Analysis of Dam Removal Alternative B
Battle Creek Salmon and Steelhead Restoration Project

California Hydropower Reform Coalition

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Summary
The Battle Creek Salmon and Steelhead Restoration Project, a high priority for resource agencies and stakeholders alike, has been subject to significant cost overruns. In this analysis, we present biological and economic information that demonstrates that removing eight dams on Battle Creek will likely result in more effective restoration of the anadromous fish habitat at equal or less total cost than the current restoration plan. The California Hydropower Reform Coalition (CHRC)[1] recommends that Memorandum of Understanding (MOU) signatories amend the current project accordingly, to increase its biological effectiveness, and to ensure efficient use of scarce public and ratepayer funds.

Background
Battle Creek is widely recognized to be the best opportunity to restore salmon habitat in the Sacramento watershed, particularly for the unique but endangered winter run chinook salmon. In 1999, after several years of negotiation, state and federal agencies and PG&E forged a landmark agreement to restore Battle Creek for threatened and endangered anadromous fish. In an MOU, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, NOAA Fisheries, California Department of Fish and Game, and PG&E agreed to remove five of eight small hydropower dams, construct screens and ladders on the remaining three dams, and undertake complex engineering measures to prevent the mixing of North and South Fork waters.

As approved by CALFED in 1999, the Battle Creek Salmon and Steelhead Restoration Project was to cost roughly $50 million ($27 million from taxpayers for construction and implementation, $20 million from ratepayers in the form of foregone power, $3 million from the Packard Foundation). Project managers proceeded to refine and finalize engineering and design plans, and pursue environmental and other regulatory approvals. Cost estimates for the MOU project have subsequently increased to $108 million or more ($65 million construction, $43 million in forgone power). This significant cost increase led supporters of the Battle Creek project to explore the feasibility of cost effective alternatives to the MOU project.

In the fall of 2003, PG&E, US Bureau of Reclamation, Metropolitan Water District, and California Hydropower Reform Coalition conducted a cost review that identified an equal cost alternative. This new alternative, Alternative B, would remove the three remaining dams on the anadromous reaches of Battle Creek and retain project powerhouses. Since January 2004, agencies and stakeholders have explored biological, economic, and procedural issues raised by Alternative B, and held a public forum in Red Bluff March 15.

[1] The California Hydropower Reform Coalition (CHRC), founded in 1997, consists of fishing, river recreation, and river conservation organizations that work to balance hydropower production with the protection and restoration of California's rivers and streams. The ultimate success of the Battle Creek Restoration Project is a high priority for CHRC's members because of the perilous status of winter run and other chinook in the Sacramento River watershed.

On March 25, agencies and PG&E informed the California Bay Delta Authority (CBDA) of their decision to reject Alternative B and seek the additional funding necessary to implement the original MOU.

PG&E and the agencies provided two primary reasons why they ultimately rejected Alternative B. They believe that the incremental environmental benefits of Alternative B are minor, compared to the MOU alternative. Furthermore, consideration of any alternative other than the MOU would require potentially lengthy renegotiation of the MOU.

The original restoration plan is a voluntary agreement between the MOU signatories. Any amendment to the MOU would need to be acceptable to these parties and then be approved by FERC and other agencies with regulatory jurisdiction. We are grateful that considerable efforts have also been made to secure the support of local landowners and other stakeholders. For an alternative to be feasible, it must provide greater environmental benefits at an equal or lesser total cost; be supported by the agencies, PG&E, and a critical mass of stakeholders; and not cause significant delays in project implementation. After several months of review, CHRC finds that Alternative B meets these criteria, with the exception of MOU signatory support. This paper outlines the bases for this conclusion.

Project Description

A detailed description of the MOU project and Alternative B is beyond the scope of this paper, but is provided elsewhere. Briefly, on the North Fork, the MOU would remove Wildcat dam and install screens and ladders on Eagle Canyon and North Battle Creek Feeder dams. On the South Fork, Coleman and South dams would be removed, with screens and ladders installed at Inskip dam. Alternative B would remove the three dams retrofitted with screens and ladders under the MOU. Both alternatives install "tailrace connectors" to reduce or eliminate mixing of North Fork water with South Fork water (discussed further below under "water quality"). The MOU, and presumably any satisfactory amendment to it, includes dedication of water rights to the environment and funding for monitoring and adaptive management.

Ecological Benefits of Alternative B

Fish biologists and river ecologists have long recognized that unimpaired, free flowing, naturally functioning river systems provide the best habitat for native riverine species. The agency signatories to the MOU affirmed this in their 1999 report, *Battle Creek Salmon and Steelhead Restoration Plan* (Kier and Ward, 1999). That report cites Cairns (1990), who suggested that "ecosystem restoration should be based on restoring ecosystem function as closely as possible to original conditions, and should not be based on experimental systems subject to mechanical failures and uncertain biological responses."

On page 49 of that report, the agencies state these principles definitively:

Kier/Ward Table 9. Biological principles that the USFWS, NMFS, CDFG, and USBR consider essential for salmonid restoration and a necessary component of any negotiated settlement with PG&E.

Biological Effectiveness – Restoration actions must incorporate the most biologically effective remedies that provide the highest certainty to successfully restore ecosystem functions and self-sustaining populations of native fish in a timely manner.
Restoring Natural Processes – Restoration actions must incorporate measures that mimic the hydrologic conditions under which Battle Creek anadromous fish resources evolved by increasing baseflows and eliminating mixing of North Fork and South Fork waters.
Biological Certainty – Restoration actions must provide maximum long-term effectiveness by minimizing long-term dependence on the integrity of man-made restoration actions and the cooperation of future project owners and operators.

Alternative B better meets these principles than does the MOU. As detailed below, Alternative B provides a suite of benefits that together provide greater assurance that ecosystem functions and fish populations will be restored. Stream channel dynamics, streamflows, and water temperatures more closely approach the natural condition of Battle Creek under Alternative B. Alternative B provides a restoration strategy that does not rely on imprecise, controversial habitat prediction models and the long-term maintenance and continuous performance of engineered structures. It returns the mainstem and the anadromous reaches of both forks of Battle Creek to a more natural state, allowing the natural variability of the river to repair and maintain, over time, the mosaic of habitats that support salmonids and other aquatic and riparian species. Alternative B is not only cheaper in the short term, it delivers greater potential for success in the long term. Thirty years from now, screens and ladders installed under the MOU will have aged and may need to be replaced. Battle Creek, under Alternative B, would continuously maintain itself, at little or no cost.

Alternative B also allows substantially more water to stay in the stream channel. Many of the biological differences between the two alternatives stem from these flow differences. When evaluating the relative merits of alternative flow regimes, the Instream Flow Council (2002) recommends analyzing hydrology, water quality, biology, geomorphology, and connectivity. The agencies and CHRC examined each of these, but came to different conclusions as to the relative importance of the differences documented.

1. Hydrology

Alternative B would provide stream flows in Battle Creek that more closely approximate the natural (unimpaired) flow. Restoration ecologists have increasingly turned to the unimpaired flow as a reference point for investigating the impacts of altered flows, and as a target for prescribing controlled flow regimes most likely to sustain natural ecosystem processes and species recovery (Stanford, 1996; Poff 1997; Richter 1997; Trush 2000). Under this paradigm, the unimpaired regime itself is not typically feasible for developed river systems. Battle Creek is a rare exception, because unimpaired flow is approachable at an equal or reduced cost from an alternative that already has agency, licensee, and public support.

The Instream Flow Council (2002) recommends that "instream flow prescriptions should provide intra-annually and interannually variable flow patterns that mimic the natural hydrograph (magnitude, frequency, duration, timing, rate of change) to maintain or restore processes that sustain natural riverine characteristics.” (Instream Flow Council, 2002, p. 93). There are measurable differences between the MOU and Alt B for each of these hydrograph components. These differences are graphically depicted in the appended figures and discussed in detail below.

- **Magnitude.** Figures S-1 through S-6 compare unimpaired, MOU and Alt B synthetic water years using the 10th, 30th, 50th, 70th, and 90th percentile daily flows from the years 1962-2002 (1997 was excluded due to an incomplete record). While winter storm events are generally comparable for all alternatives, Alt B streamflows in spring, summer, and fall are significantly higher than MOU flows for all reaches and water year types: 50-55% more over the course of the year, and 80-130% more in summer. Unimpaired and Alt B flows show significant interannual changes in late summer/early fall low flow periods, whereas the MOU falls to the same, substantially lower flow for each reach and year type. Interannual baseflow variability under Alt B would cause physical habitat, temperature, and passage conditions to vary somewhat from year to year, allowing fish to exploit outstanding habitat conditions on a recurring basis.
- **Frequency.** Comparative analysis of Figures H-1 to H-4 (hydrographs of water years 1962-2002) shows that low to mid level pulses are more frequent in the late fall and early spring under Alt B. The geomorphic discussion below outlines how Alt B may provide flows capable of mobilizing sediment more frequently than the MOU.
- **Duration.** Clear differences in the duration of flows are illustrated in Figures E-1 to E-6, comparative flow exceedence curves for the mainstem, Eagle Canyon, and Inskip reaches. For example, if flows below 50 cfs were found to form a natural barrier in Eagle Canyon, Figure E-5 shows MOU flows would exceed that amount in summer 20% of the time (24 days), based on the 1962-2002 period of record. Alt B flows would exceed 50 cfs 97% of the time (118 days).
- **Timing.** Figures S-4 to S-6 illustrate a significant difference in the descending limb of the hydrograph, the transition from the winter (high) to summer (low) flow season. The onset of lower and less variable baseflows under the MOU is also substantially earlier (30-60 days). This effect also shows up each and every year on Figures H-1 to H-4. This particular feature of the hydrograph is important for anadromous fish for at least two reasons. First, outmigrating smolts ride the descending limb of the hydrograph. Second, higher flows extending farther into the summer months serve as a buffer to thermal stress for all species and life stages. The gradual, seasonal transition from higher to lower flows also plays a key role in the life histories of many other aquatic and riparian species.
- **Rate of change.** At least three issues arise related to rate of change. First, smaller peak events have a much more abrupt interface with the baseflow under the MOU than under Alt B or unimpaired (Figures H-1 to H-4), possibly causing fish stranding. Second, under unimpaired and Alt B flow regimes, the transition from the winter (high) to summer (low) flow season is long and gradual. The onset of lower, stable baseflows under the MOU is much earlier, and more abrupt. Finally, on the South Fork, for most year types, the transition between the summer and winter flow releases below Inskip dam (40 and 86 cfs, respectively) does not occur at the more gradual rate seen under unimpaired and Alt B.

2. Water Quality

- **Temperature**

Water temperature is a key factor in Battle Creek's restoration potential for salmon, especially the endangered winter run chinook. Figures T-1 to T-8 are longitudinal temperature profiles developed for Battle Creek by PG&E in 2001 (SNTEMP). The MOU, Alternative B, and an unimpaired alternative are presented for Jun-Sep, for normal and dry/warm year types. For the purposes of this analysis, Alternative B was constructed from a "hybrid" of two pre-existing SNTEMP alternatives – a full decommissioning alternative (SNTEMP Alt 6) for the South Fork, and a 6 dam removal alternative for the North Fork and Mainstem (SNTEMP Alt 4). The full modeling assumptions for SNTEMP are beyond the scope of this paper, but can be reviewed at www.calhrc.org/battlecreek.htm.

Figures T-1 to T-8 show that Alternative B is predicted to provide cooler water than the MOU in the North Fork, South Fork, and mainstem Battle Creek in all months, for both normal and warm/dry years. Various life stages of four races of chinook salmon and steelhead utilize Battle Creek each month of the year. Assuming temperature thresholds of 66°F for juveniles, 62°F for prespawning adults, and 58°F for incubating eggs (Armour, 1991), in an average June, Alternative B provides an additional 8.7 miles of rearing habitat in the mainstem and South Fork, and an additional 2.5 miles of adult holding habitat in the forks of Battle Creek. In September, Alternative B provides an additional 8.5 miles of adult holding habitat in the mainstem and South Fork Battle Creek and 1.3 miles of egg incubating habitat in the North Fork.

These results are conservative. As described in detail in the following paragraphs, limitations presented by the "hybrid" approach to modeling Alt B, and the flow assumptions of SNTEMP itself combine to significantly understate the temperature benefits of the 8 dam removal alternative. Corrected, SNTEMP would show even greater temperature benefits to Alternative B.

Figures C-1 through C-3 compare RMI/Navigant median monthly streamflows to the SNTEMP modeled flows in the North Fork (Eagle Canyon), South Fork (Inskip) and Mainstem (above Coleman PH), for each alternative. RMI/Navigant median flows are shown with braces denoting the 10th and 90th percentile flows for water years 1962-2002 for that month.

While the flows used in the SNTEMP model for the most part approximate the median flows for the unimpaired and MOU alternatives, they are consistently less than median flows of Alt B. This is especially true on the mainstem (Figure C-1), where SNTEMP normal and dry year flows for Alt B are both less than the 10% synthetic dry year. Further, as discussed above (i.e., hydrology discussion), Alt B maintains considerably more variability from year to year throughout the descending limb of the hydrograph (June and July) and the low flow period (August and September), as shown in Figures S-4 to S-6, and in the 10th/90th braces in Figures C-1 to C-3.

In many year types, Alt B flows approach and equal the volume of flow in the unimpaired alternative modeled by SNTEMP. Interannual variability in the Alt B hydrograph could provide recurring optimal temperatures in the forks and mainstem of Battle Creek. Other than June, the MOU alternative does not share this characteristic. A careful comparison of

Figures C-1 to C-3 to SNTEMP suggests that, corrected for flow, SNTEMP would show substantial temperature benefits for Alt B relative to the MOU.

There is an additional consideration with the SNTEMP mainstem temperatures. According to the validation and calibration sections of SNTEMP, the model is not very accurate for predicting mainstem temperatures.

> …[V]alidation showed that, except for the Mainstem, the updated TRPA-SNTEMP model achieved the same level of accuracy as in the calibration phase. Figures 2–7 compare the model's predictions with the observed daily average temperature at six stations in various reaches. Good agreement is evident. In Figure 7, however, there is a noticeably large discrepancy for the Mainstem just above the Coleman Powerhouse. This large discrepancy also occurred during the 1989 calibration. Because the main objective of the present project is to predict temperature characteristics for upper Battle Creek in the North Fork and the South Fork river channels, the larger discrepancy predicted in the Mainstem is not a major concern. Therefore, no attempt was made to adjust the model. (SNTEMP 2001, Sec.3, pp. 3-4.)

SNTEMP Figure -7. Validation for Mainstem Battle Creek

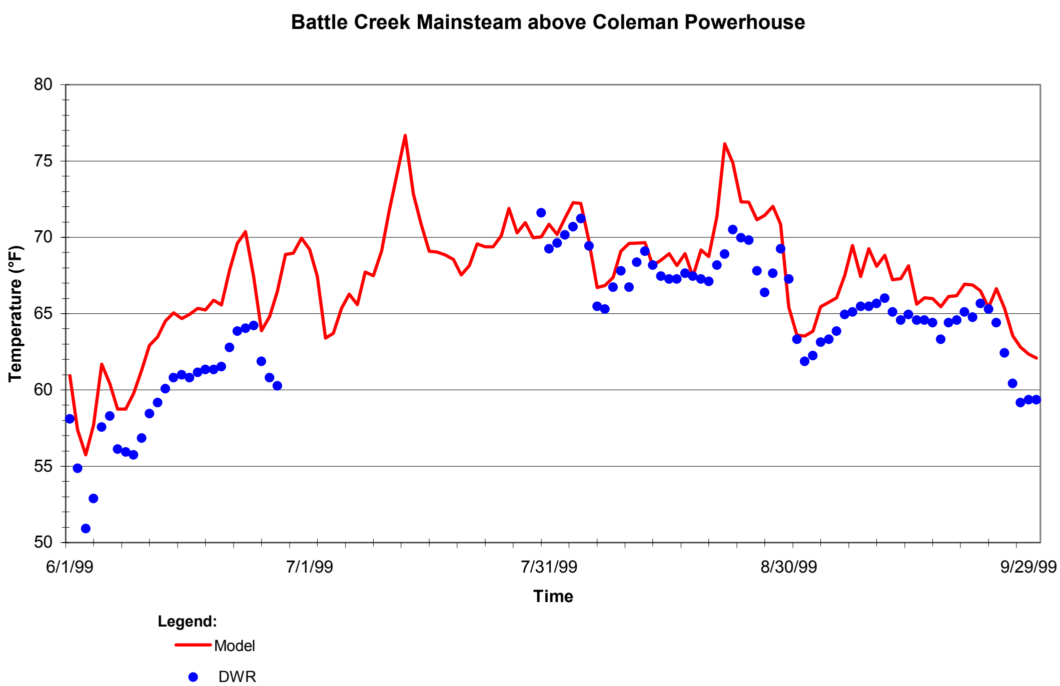

Figure 7. Model validation test for Mainstem Reach, 1999 daily average water temperature.

The 1999 validation test shows SNTEMP overestimated mainstem temperatures by 3-5°F in June, and 1-4°F in September. Figures T-1 to T-8 show the mainstem often at or above the upper limits for many life stages of target species. Accounting for the SNTEMP modeling error (which would affect all alternatives), the underestimate of Alt B "normal" flows, and the interannual variability of Alt B flows, would show substantially more viable habitat in the mainstem of Battle Creek under Alt B. Because these uncertainties bear materially on the temperatures attainable by the Battle Creek Restoration Project, project proponents and reviewers should recalibrate SNTEMP mainstem based on 2000-2003 recorded temperature data, and run Alt B with corrected flow estimates.

The following two tables compare river miles below temperature thresholds for the MOU and Alt B under SNTEMP as shown in figures T-1 and T-4, and under a conservatively corrected SNTEMP. Marginal mileage *is not* inclusive of optimal mileage. For example, SNTEMP shows the MOU provides 2.4 miles of habitat below 57.2°F (optimal) and 20.2 miles of habitat between 57.2°F and 66°F (marginal) for juvenile chinook salmon in a normal June. Alt B provides 8.7 miles of additional marginal habitat.

Table 1. June temperature/river miles relationship for various life stages. SNTEMP shown as published in 2001, and conservatively adjusted for the errors described above (1°F cooler on mainstem for all alternatives, additional 1°F for Alt B mainstem). Optimal and marginal temperature thresholds from CDFG/USFWS.

June	Steelhead Smolts		Chinook Embryos		Chinook Juveniles		Chinook Smolts		Adult Chinook	
	<56.4°F	<59°F	<59.5°F	<61°F	<57.2°F	<66°F	<62.6°F	<68°F	<60°F	<66°F
SNTEMP	Opt.	Mar.	Opt.	Mar.	Opt.	Mar.	Opt.	Mar.	Opt.	Mar.
MOU (mi.)	0.0	7.9	9.4	3.1	2.4	20.2	15.8	15.6	10.8	11.8
Alt B (mi.)	0.0	7.7	9.5	4.8	2.4	28.9	18.0	14.1	11.2	20.1
Difference	0.0	-0.2	0.1	1.7	0.0	8.7	2.2	-1.5	0.4	8.3
SNTEMP Adjusted										
MOU (mi.)	0.0	7.9	9.4	3.1	2.4	22.9	15.8	16.3	10.8	14.5
Alt B (mi.)	0.0	7.7	9.5	4.8	2.4	29.7	22.3	9.8	11.2	20.9
Difference	0.0	-0.2	0.1	1.7	0.0	6.8	6.5	-6.5	0.4	6.4

River miles below NBCF and South Dams for the NF and SF, respectively.

Table 2. September temperature/river miles relationship for various life stages. SNTEMP is shown as published in 2001, and adjusted for modeling error described above (1°F cooler on mainstem for all alternatives). Optimal and marginal temperature thresholds from CDFG/USFWS.

September	Steelhead Smolts		Chinook Embryos		Chinook Juveniles		Chinook Smolts		Adult Chinook	
	<56.4°F	<59°F	<59.5°F	<61°F	<57.2°F	<66°F	<62.6°F	<68°F	<60°F	<66°F
SNTEMP	Opt.	Mar.	Opt.	Mar.	Opt.	Mar.	Opt.	Mar.	Opt.	Mar.
MOU (mi.)	6.8	7.3	15.4	2.1	9.2	22.9	22.2	9.9	16.2	15.9
Alt B (mi.)	7.1	8.1	16.0	4.7	10.0	22.1	28.9	3.2	16.7	15.4
Difference	0.3	0.8	0.6	2.6	0.8	-0.8	6.7	-6.7	0.5	-0.5
SNTEMP Adjusted										
MOU (mi.)	6.8	7.3	15.4	3.0	9.2	22.9	25.1	7.0	16.2	15.9
Alt B (mi.)	7.1	8.1	16.8	7.0	10.0	22.1	30.8	1.3	19.2	12.9
Difference	0.3	0.8	1.4	4.0	0.8	-0.8	5.7	-5.7	3.0	-3.0

River miles below NBCF and South Dams for the NF and SF, respectively.

Alternative B provides equal or greater optimal thermal habitat for each life stage.

- **Mixing of North and South Fork waters**

A major purpose of the Battle Creek project is to prevent the mixing of water from the North and South Forks. The tailrace connectors being constructed for this purpose total $13.7 million, or 28% of the total construction cost of the project. However, mixing will still occur under the MOU project during routine maintenance and other planned outages on the South Fork. Planned annual outages are estimated at four days each for the South, Inskip, and Coleman powerhouses. Concerns have been raised about the possibility of resident juveniles imprinting on the North Fork water during these periods.

Under Alternative B, shutting down any powerhouse on the South Fork requires shutting down all powerhouses and not diverting at Volta, eliminating 12 days of planned mixing per year. Under Alt B, the only cause of North Fork water entering the South Fork would be emergency shutdowns, and in that event, there would be substantially less water in the power system to mix.

Table 3. Mixing of North and South Fork Waters. Flow estimates from RMI/Navigant power model.

MOU	Median powerhouse flow (cfs)	Maximum powerhouse flow (cfs)	Days of mixing/year
South PH	71	150	4 + unplanned
Inskip PH	132	284	4 + unplanned
Coleman PH	151	380	4 + unplanned
Alt B			
South PH	71	128	Unplanned only
Inskip PH	71	128	Unplanned only
Coleman PH	71	128	Unplanned only

3. Biology

- **Habitat**

The MOU alternative makes use of 1988 PHABSIM data to prescribe “biologically optimum” flows that are just a fraction of naturally occurring flows in Battle Creek. For example, the MOU summer minimum flow in Eagle Canyon is 35 cfs, which is 73% less than the median unimpaired summer low flow, and 35% less than the modeled driest day on record (Oct 27, 1993). Scientists have criticized PHABSIM generally (Castleberry, 1996), as well as the types of approaches used in the Battle Creek study. PHABSIM is considered an especially poor predictor of hydraulic conditions for channels with the complexity and gradients that characterize much of Battle Creek. For a project of this size and importance to listed species, it is surprising that so much weight was given to the hydraulic habitat analysis, and that it does not incorporate better methodologies. The Battle Creek PHABSIM study does not include transects in two dimensions, it does not include confidence intervals, it does not incorporate temperature in Weighted Useable Area, and it has not been validated, despite the fact that interim flows based upon it began in 1995 (Williams, 1995; Ghanem, 1996; Kondolf, 2000; Payne, 2003).

Despite these shortcomings, the physical habitat predicted through PHABSIM was the primary basis for selecting "optimum" flows for the MOU restoration project. Responding to comments to the draft 1999 Kier/Ward report, the authors state (p. 140), "…[T]he original, stated intent of the Biological Team process was to use an IFIM/WUA based approach to determine appropriate flows for fish in Battle Creek. The SNTEMP was to be a check to make sure that temperatures were not too high … [M]anaging flows based primarily on temperature was never a primary objective of the Biological Team." Given the importance of temperature to recovery of Battle Creek salmonids and the relatively marginal temperatures attained under MOU flows, project proponents may reconsider this approach.

Because the MOU minimum flow releases approach the WUA maxima, project proponents have claimed that the MOU project restores "90-95% of the habitat" of Battle Creek. Some have used this claim to argue against Alt B because it is assumed that the best that can be achieved through Alt B over the MOU is an additional 5% habitat. The hydrological and temperature benefits of Alt B alone show this not to be the case (80-130% more water in summer, and a conservative 3-7 miles (8-18%) more optimal thermal habitat in critical months).

- **Ecosystem vs. single species approach**

Much of the attention and planned investment in Battle Creek is focused on a very narrow list of species. This is appropriate given the enormous social and regulatory mandate to recover endangered salmon. The single-species approach to river management has not always yielded long-term success, however. An ecosystem approach strives to maintain overall ecosystem complexity, recognizing a community of native species has adapted to a dynamic range of disturbance and stability. The variable flows, temperatures, and physical habitat provided under Alt B most closely approximate the conditions that occurred prior to construction of the hydropower project on Battle Creek. These are the conditions most likely to sustain the processes and biotic communities that promote recovery for the target species, and most likely to support a functioning ecosystem.

4. Geomorphology

The Nature Conservancy prepared a geomorphic analysis that compares the MOU and Alt B (Roberts 2004). It concludes that, since the three remaining dams in the MOU project do not significantly alter high flow events, and the dams themselves are not sediment traps, the MOU does not impair geomorphic stream function. The TNC report identifies 2250 cfs as the 1.5 return flow for Eagle Canyon, and 3250 cfs for the Inskip reach. The RMI/Navigant model, modified to utilize the USGS record of average daily flows at Coleman (USGS 11376550), projects those flows occurring far less frequently, and in the Inskip case, not in the period of record (1962-2002). The differences between the models could be due to different partitioning fractions, or use of instantaneous peak flow rather than average daily peak flow.

The following analysis applies the TNC methodology to the RMI/Navigant flow model output. We determined a 1.5 year return flow by ranking the unimpaired peak daily flow for water years 1962-2002 (1997 excepted) and selecting the 27th ranked flow (Weibull method). For the mainstem, Eagle Canyon, and Inskip reaches, respectively, those flows were 2390 cfs, 1246 cfs, and 590 cfs. Adopting the assumption that sediment movement initiates at 60% to 80% of the 1.5 year recurrence flow, we determined the number years

(1962-2002, 1997 excepted) in which average daily flows exceeded threshold flows for two or more days under the unimpaired, Alt B, and MOU alternatives. We also note the total number of days that thresholds would be exceeded over the same period.

Table 4. Battle Creek Geomorphology

Battle Creek Reach (geomorphic threshold flows, 0.6-0.8 of 1.5 return flow)	Number of years with two or more days at or above threshold flow, 1962-2002 (total number of days)					
	Unimpaired		Alt B		MOU	
	0.6	0.8	0.6	0.8	0.6	0.8
Mainstem (1434-1912 cfs)	29 (452)	24 (249)	28 (373)	23 (218)	27 (295)	21 (174)
Eagle (748-997 cfs)	29 (452)	24 (249)	28 (325)	23 (194)	24 (256)	20 (160)
Inskip (354-472 cfs)	29 (452)	24 (249)	29 (452)	24 (249)	27 (306)	22 (184)

The Weibull recurrence interval for sediment threshold flows of two or more days is 1.4-1.7 for Unimpaired, 1.4-1.8 for Alt B, and 1.5-2.1 for the MOU. These results show Alternative B mobilizes sediment more frequently than the MOU alternative, and for more total days, using simulated historic hydrology. Periodic sediment mobility plays an important role in the morphology and composition of the stream channel and substrate, and ensures spawning gravels are clean and well distributed.

The effect of diverting approximately half of the summer flow at Eagle Canyon (56%) and Inskip dams (46%) on fine suspended sediment, fine organic particles, and drifting aquatic macroinvertebrates was not analyzed.

5. Connectivity

Concerns have been raised elsewhere at length and in detail about the risk of long-term reliance on fish screens and ladders to pass fish over dams on Battle Creek. Exchanges between the Battle Creek project managers and peer reviewers on technical aspects of screen and ladder design demonstrate that "the state of the art" is controversial and always changing. Removing three additional dams would reduce uncertainty of upstream and downstream passage at dam sites for all life stages of salmonids and for other species, and yield considerable cost savings immediately and over time. Alt B would also avoid considerable construction impacts and costs, including permanent roads and parking lots in the riparian corridor. These MOU project features have ecological, geomorphic, and aesthetic consequences.

There is also concern about fish passage at natural barriers under the flow regime prescribed by the preferred (MOU) alternative. Monitoring activities have identified a natural barrier on the North Fork for adult spring chinook at interim flows (USFWS, 2004, public comments to Battle Creek Working Group). Specifically, adults and redds have been seen below this barrier, but not above it. MOU minimum flows at Eagle Canyon dam are 35 cfs during the low flow season. Figures I-1 and I-2 show that interim flows on the North Fork in 2002 and 2003 are similar to what can be expected under the MOU. Alternative B baseflows are consistently and significantly higher, and vary from year to year, both of which would tend to reduce passage uncertainty at this and other potential barriers on Battle Creek.

Adaptive Management

Many, but not all, of the flow related issues described above could be addressed with a robust and flexible adaptive management program. The MOU provides for a $3 million Water Acquisition Fund (WAF) and $3 million Adaptive Management Fund (AMF) to be used to purchase additional flow. How much water does this buy, and how flexible is the program?

The MOU, as amended in the Adaptive Management Plan, spells out specific procedures for purchasing flows through the WAF and AMF. The first ten years of purchases would be paid at the real-time cost of the actual power forgone. In year 11, any remaining funds can be used to purchase flows through the end of the license term (2026) at the net present value of the estimated future power cost of such flows. If the WAF and AMF are depleted and flows are still needed, PG&E could provide up to an additional $6 million in adaptive management costs (flow and facility modifications). The agencies agreed to support the flow rates in effect in 2026 in the next license.

At the request of the resource agencies, Navigant consulting estimated the purchasing power of the two funds to be 8,000 AF ($3 million WAF) and 14,000 AF ($6 million WAF+AMF) per year, respectively, assuming the following:

- <u>No flow purchases until 2014.</u>
- $50/mWh replacement cost of power throughout the year, 2.5 % inflation, 9.53% discount rate
- No objection by PG&E to the flow increase. PG&E reserves the right to oppose any flow purchase, but it agrees to implement the first $3 million of flow purchases even if it disagrees while parties pursue dispute resolution. The second $3 million cannot be used for flow unless PG&E concurs or FERC so orders.

Any of the following would reduce the purchasing power of the two funds.

- Flow purchases prior to 2014, for example, to ensure passage at natural barriers in Eagle Canyon.
- Power prices above $50/mWh – overall, or for the months, days, or hours in which flow is purchased. Power prices are above their average annual rate during summer months, when flow purchases are most likely to be made. For the first ten years, flow purchases would be sensitive to possibly extreme prices on high demand, hot days.
- Increase in the inflation rate
- Reduction in the applicable discount rate

Figures A-1 to A-3 show annual flows expressed in acre feet for three alternatives (MOU, Alt B, Unimpaired) across 5 synthetic year types, plus the mean. For the mainstem and Eagle Canyon, the MOU provides roughly half the flow of Alt B, and a third of the unimpaired flow. MOU flows are relatively higher on the South Fork but are still substantially lower than Alt B flows. Annual acre feet flows are also shown for the MOU alternative plus the two adaptive management flow funds. For illustration purposes, it is assumed the fund is applied equally across both forks. Figures A-4 to A-6 show summer months only, and assume adaptive management purchases would occur only in June through September, again equally in both forks.

For nearly all reaches and year types, Alt B provides more flow than can be achieved through the adaptive management funds. In a median summer, Alt B provides 80% more flow in the mainstem than the MOU, and 25% more than the MOU plus the WAF and AMF. In Eagle Canyon, Alt B provides 127% more flow than the MOU in a median summer, and 32% more than the MOU plus the WAF and AMF. For the Inskip reach, Alt B provides 86% more flow than the MOU in a median summer, and 9% more than the MOU plus the WAF and AMF. These flow benefits would be provided without the 5-8 year delay, $6 million cost, or considerable uncertainty associated with the flow purchase procedures provided in the MOU.

Table 5. Median summer flows (Jun-Sep), by reach.

Reach	Alt B	MOU	MOU+$3m	MOU+$6m
	AF	% of Alt B	% of Alt B	% of Alt B
Mainstem	57,951	56	69	80
Eagle	22,112	44	62	75
Inskip	18,382	54	75	92

Economic Considerations

As noted above, in the Fall of 2003, PG&E, US Bureau of Reclamation, Metropolitan Water District, and California Hydropower Reform Coalition updated the cost estimates of the Battle Creek project, including the MOU, the NEPA/CEQA alternatives, and three new alternatives that included the removal of additional dams. Alternative B arose out of that effort, when it was shown to be $2 million less expensive than the MOU alternative.

Since presenting those findings to the California Bay Delta Authority in January, 2004, CHRC worked with David Marcus, an economist and energy policy analyst, to further refine the cost differential between the MOU and Alternative B. Marcus's findings, revised and annotated to reflect the April 11, 2004 draft cost estimates, are attached as Appendix II, however his conclusions bear emphasis. **Under all scenarios, it appears that costs under Alternative B are such that, if CBDA funds are held constant, PG&E could be compensated for the net present value of 50 years of renewable replacement power.**

Process and Schedule Considerations

At the March 15 public meeting, the MOU signatories estimated it would take an additional 3 years to pursue Alternative B rather than the MOU. This estimate is a best-case scenario for the MOU alternative (assuming expedited and uncontested approvals by FERC and other agencies with regulatory jurisdiction) and a worst-case scenario for Alternative B (namely, two year negotiation of a MOU amendment and publication of a supplement to the DEIS/R). While we agree that a three year delay would warrant careful balancing of the considerable ecological benefits and risk reduction provided under Alt B against the cost, funding, and species recovery risk of additional delay, we do not believe a three year delay is a reasonable estimate. With willing parties, it would be feasible to bring Alternative B to the point where construction may commence by the end of 2005. Specifically, the CBDA would conditionally approve funding this summer for the MOU alternative or Alternative B, depending on which receives final regulatory approvals. The draft DEIS/R would be supplemented to incorporate Alternative B and would be published for further public comment, after which the lead agencies would finalize the document. If Alternative B were the preferred alternative, the MOU would be amended to the limited extent necessary to implement Alternative B.

The regulatory approval process for the Battle Creek project, prior to construction, is necessarily complex, even for the MOU alternative. CBDA must review and approve the project for additional funding. NOAA Fisheries must undertake formal consultation under the Endangered Species Act section 7(a)(2). The State Water Resources Control Board must certify the project complies with the Clean Water Act section 401(a)(1). The Army Corps of Engineers must issue a Clean Water Act section 404 permit. PG&E must complete a California Public Utilities Commission Section 851 proceeding to divest or encumber a utility asset. FERC must approve a license amendment. All of these approvals are subject to public comment, administrative appeal, and judicial review. Voluntary adoption of Alt B by parties would likely ease and even expedite these approvals. For example:

- Section 401(a) of the Clean Water Act requires a project to attain all beneficial uses and other water quality standards, to the extent controllable. The record developed here and elsewhere demonstrates that Alt B is a feasible alternative that is more likely to comply with applicable water quality standards, including the designated beneficial use of coldwater fish and the anti-degradation policy (which prohibits an adverse impact on the coldwater fishery as it existed in 1967).
- NOAA Fisheries will issue an incidental take statement under the Endangered Species Act. With no screens or ladders, lower temperatures, more natural hydrograph, and better passage at natural barriers, it is likely Alt B results in less take than the MOU.
- The California Public Utilities Commission must find the Battle Creek project is reasonable and prudent use of ratepayer funds. In the current MOU, PG&E's ratepayers will pay $43 million in forgone power costs. In Alt B, PG&E's ratepayers would bear the same burden, but in return get a completely restored river, 80% more water instream (mainstem), no ongoing responsibility for operation and maintenance, including repair and eventual replacement of screens and ladders, and no $6 million adaptive management duty.
- If the Battle Creek Project is to become a reality, the CBDA must approve supplemental funding. Assuming action this summer, CBDA will necessarily condition any funding approval on subsequent regulatory approvals, whether for the MOU or Alternative B. In the face of large cost increases, project managers can demonstrate flexibility and adaptive management by amending the project to realize greater project benefits at no additional cost.

In addition to the regulatory and funding processes, there has been a long and extensive public outreach process for the Battle Creek Project. Many stakeholders, including and especially local stakeholders in the watershed, have attended meetings and coordinated with project managers and proponents for many years. Not all are in agreement with the MOU project, nor can it be assumed that all would support Alt B. However, stakeholder support is a necessary component of any Battle Creek project, regardless of the alternative.

Conclusion

To sum up the advantages of Alternative B as compared to the MOU restoration project, we reaffirm and restate the original principals laid out by the resource agencies in their 1999 report (Kier/Ward 1999):

- **Biological Effectiveness** – Alternative B incorporates the most biologically effective remedies that provide the highest certainty to successfully restore ecosystem functions and self-sustaining populations of native fish in a timely manner.
- **Restoring Natural Processes** – Alternative B incorporates measures that more closely mimic the hydrologic conditions under which Battle Creek anadromous fish resources evolved, by increasing baseflows, restoring flow variability, reducing temperature, and reducing, to a greater extent than the MOU, the mixing of North Fork and South Fork waters.
- **Biological Certainty** – Alternative B provides maximum long-term effectiveness by minimizing long-term dependence on the integrity of man-made restoration actions and the cooperation of future project owners and operators.

Our analysis has shown that the hydrograph under Alt B – in particular its descending limb in spring, and interannual variability during the low summer flow season – provides better conditions for the recovery of threatened and endangered salmon, steelhead, and other aquatic species. Temperature models reveal some of the cooling benefits of Alt B, and would show more with appropriate adjustments. Finally, in areas such as fish passage at natural barriers, and adaptive management of flows, Alt B provides a greater degree of benefit, up front and over the long term, than does the MOU.

The restoration of Battle Creek is a critical priority for agencies, PG&E, and stakeholders alike. The scarcity and value of the natural resources of Battle Creek, and the public resources necessary to restore them, demand of all of us an extra measure of reflection, flexibility, and innovation. The emergence of an alternative that provides a greater degree of restoration for equal or less cost is a rare opportunity. We respectfully encourage project supporters to consider these findings, and to act on them.

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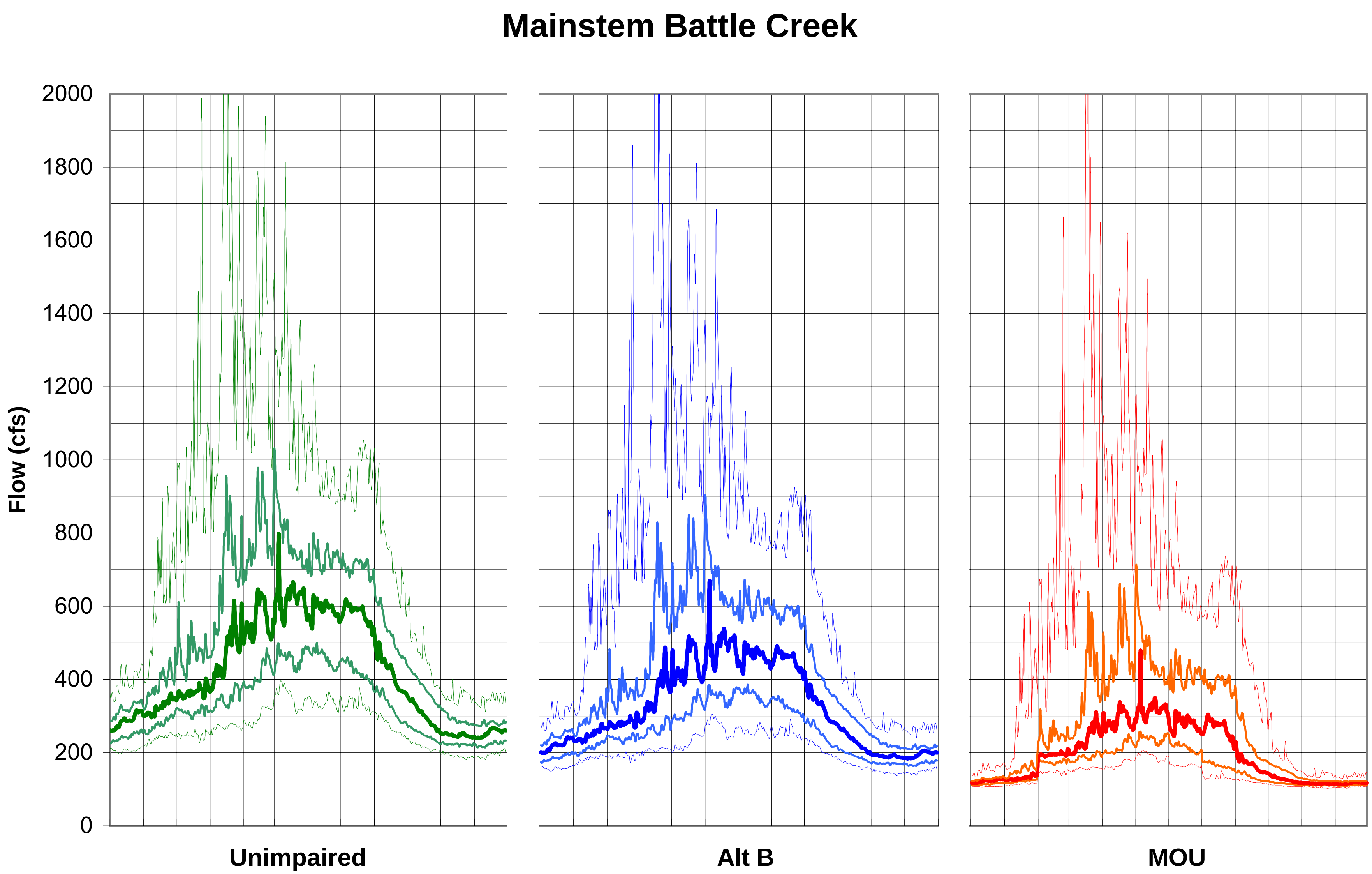
Appendix I

Figures

Figure S-1, Mainstem

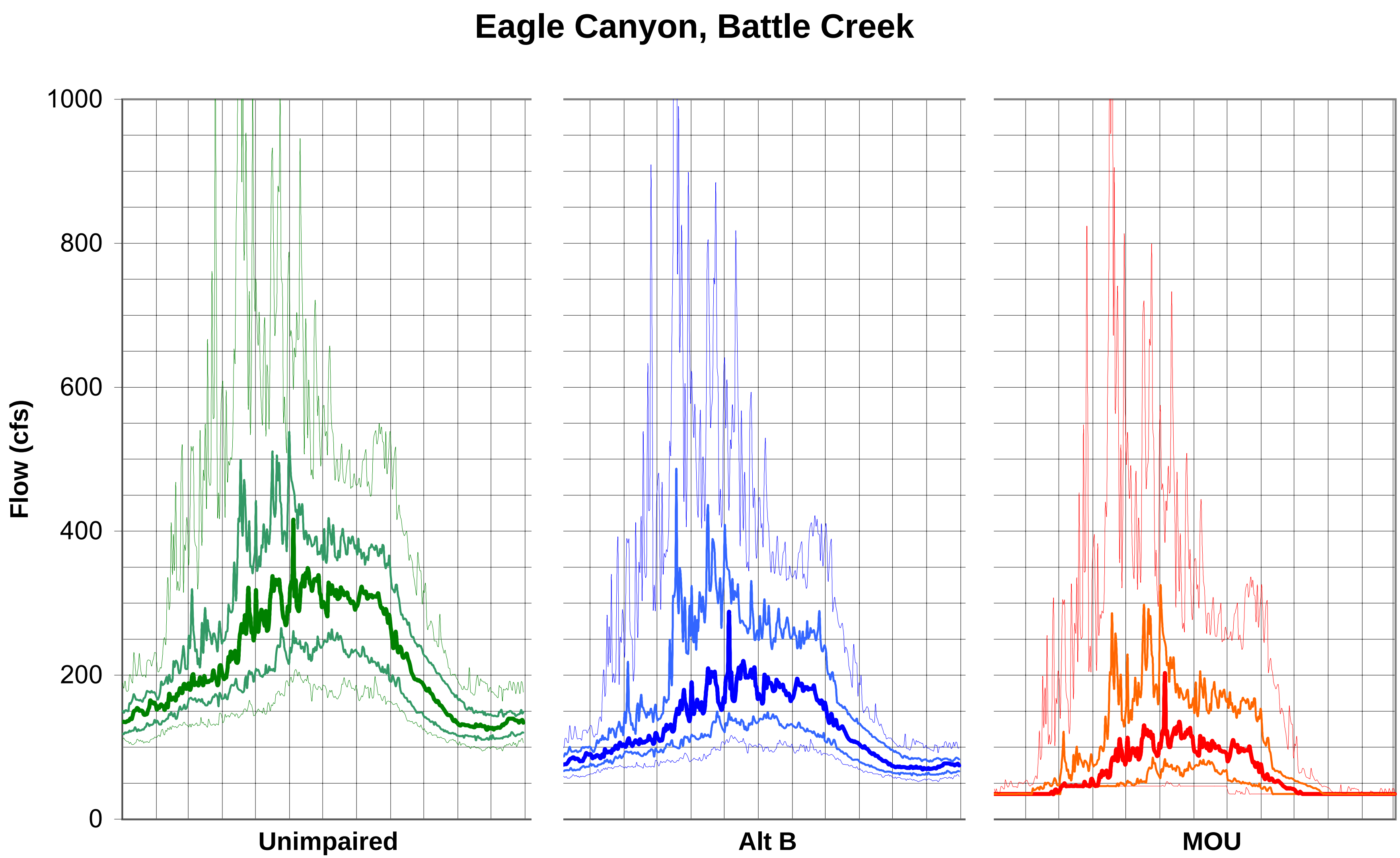
Synthetic Water Year Comparison



WY 1962-2002 daily flow data from USGS 11376550 and modified RMI/Navigant model. 10%, 30%, 50% (BOLD), 70%, and 90% percentile flow for Oct 1 -Sep 30 in the period of record. 1997 data excluded.

Figure S-2, Eagle Canyon

Synthetic Water Year Comparison

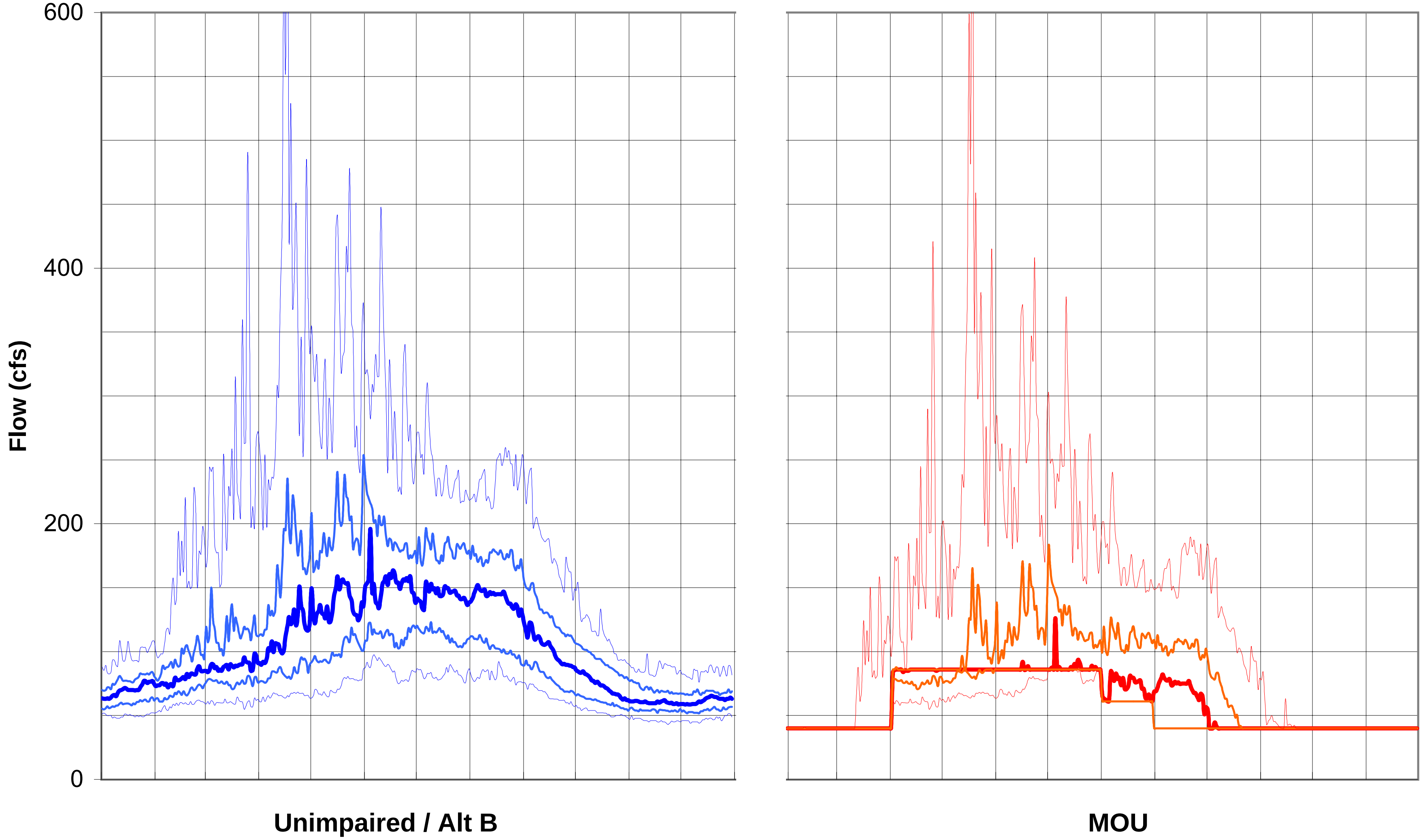


WY 1962-2002 daily flow data from USGS 11376550 and modified RMI/Navigant model. 10%, 30%, 50% (BOLD), 70%, and 90% percentile flow for each day in the period of record. 1997 data excluded.

Figure S-3, Inskip Reach

Synthetic Water Year Comparison

Inskip Reach, Battle Creek

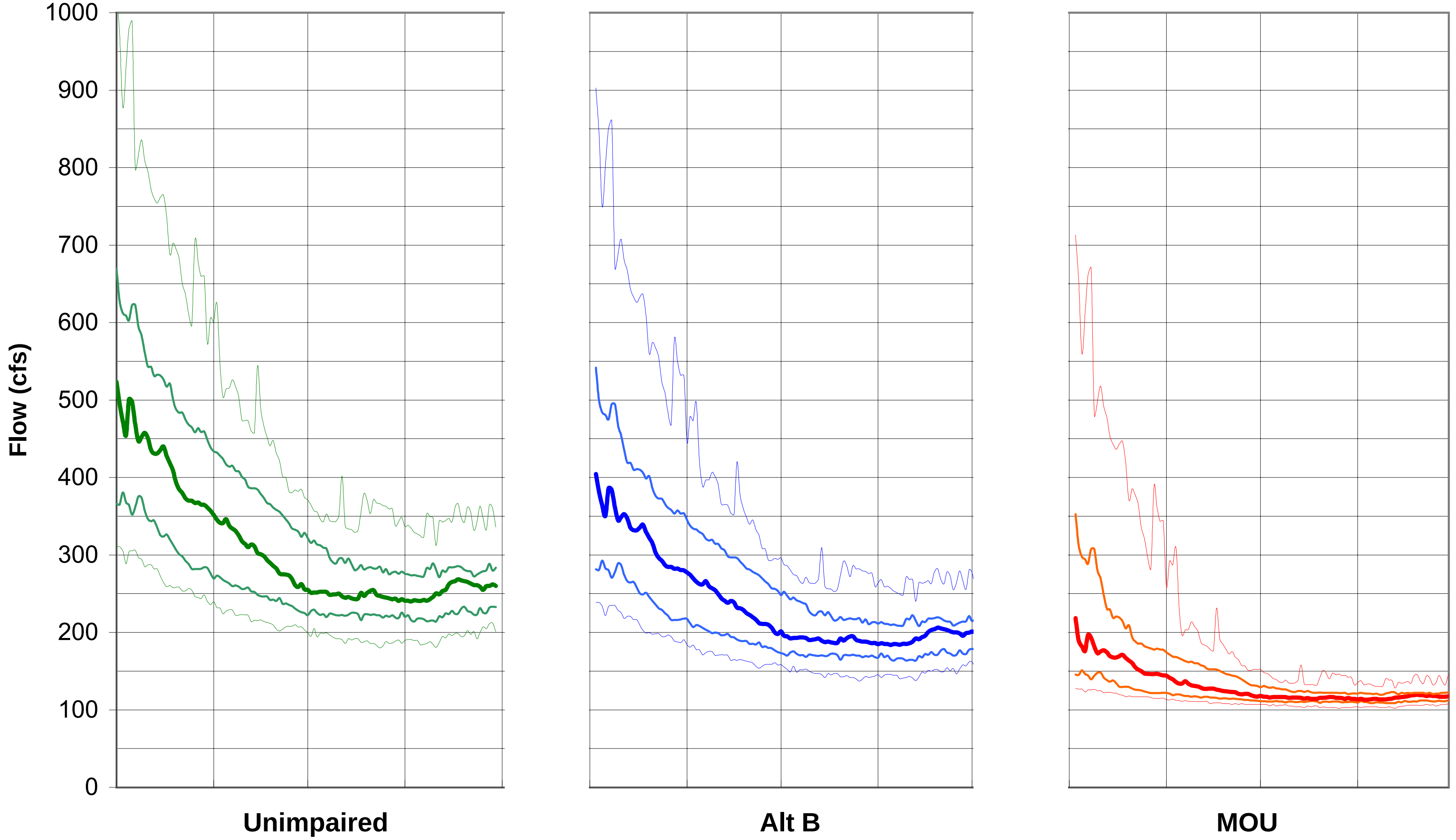


WY 1962-2002 daily flow data from USGS 11376550 and modified RMI/Navigant model. 10%, 30%, 50% (**BOLD**), 70%, and 90% percentile flow for each day in the period of record. 1997 data excluded.

Figure S-4, Mainstem Summer

Synthetic Water Year Comparison

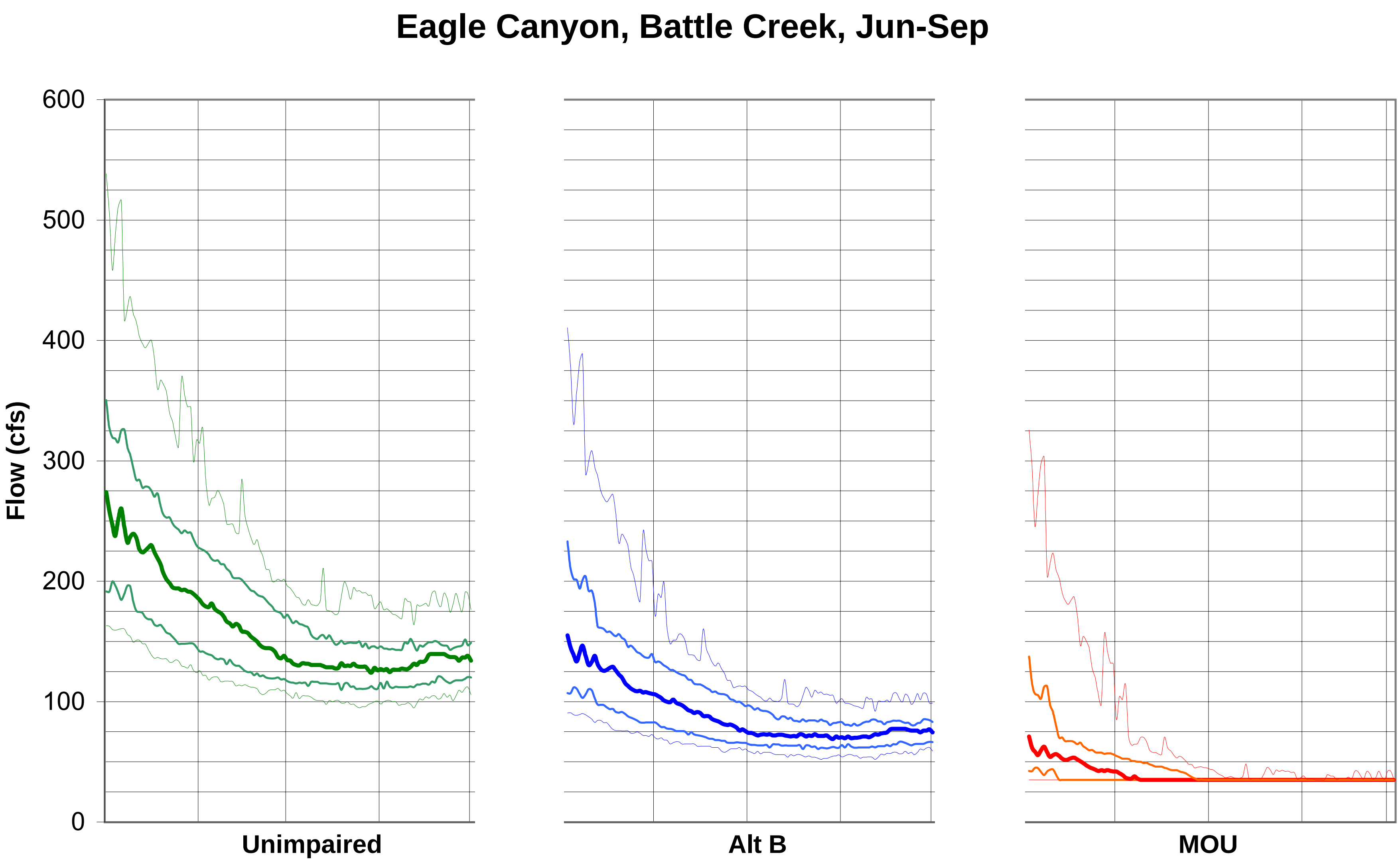
Mainstem Battle Creek, Jun - Sep



WY 1962-2002 daily flow data from USGS 11376550 and modified RMI/Navigant model. 10%, 30%, 50% (median), 70%, and 90% percentile flow for Jun-Sep in the period of record. 1997 data excluded.

Figure S-5, Eagle Canyon Summer

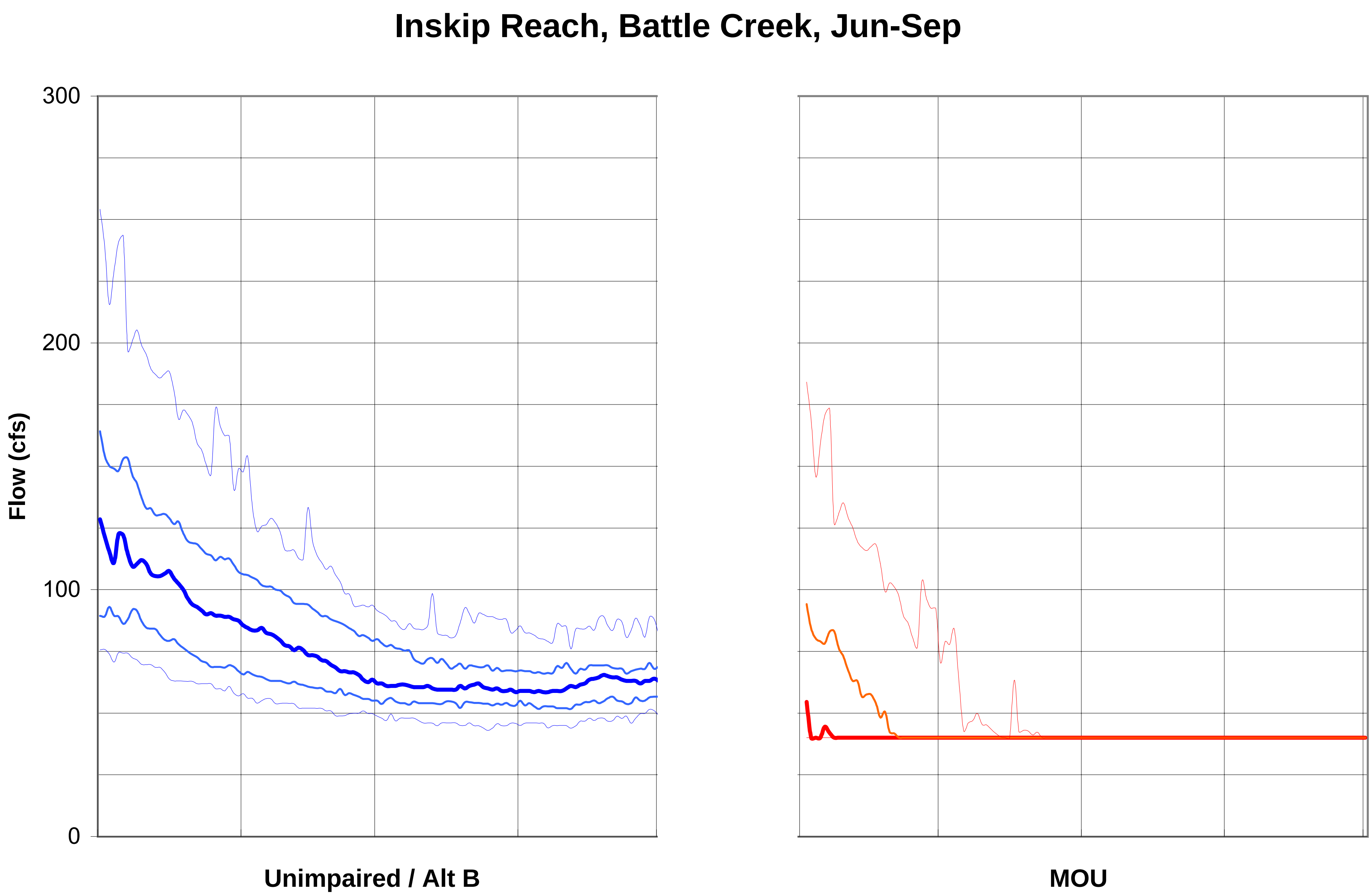
Synthetic Water Year Comparison



WY 1962-2002 daily flow data from USGS 11376550 and modified RMI/Navigant model. 10%, 30%, 50% (BOLD), 70%, and 90% percentile flow for Jun-Sep in the period of record. 1997 data excluded.

Figure S-6, Inskip Reach Summer

Synthetic Water Year Comparison

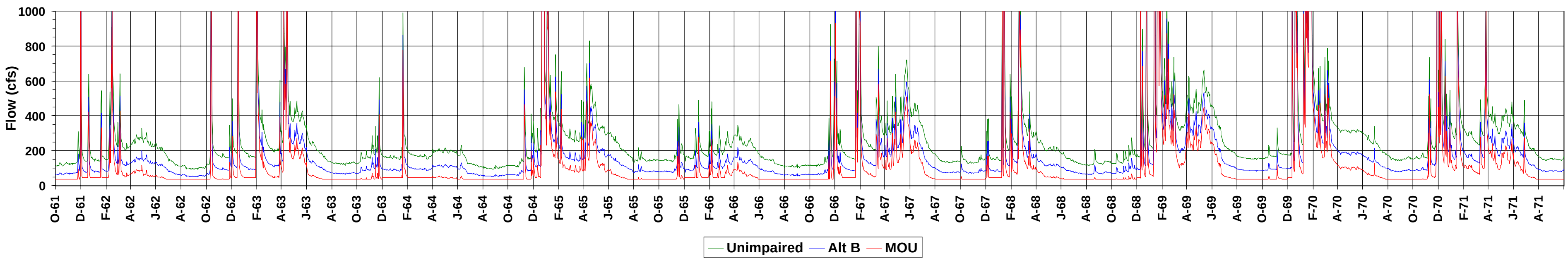


WY 1962-2002 daily flow data from USGS 11376550 and modified RMI/Navigant model. 10%, 30%, 50% (BOLD), 70%, and 90% percentile flow for Jun-Sep in the period of record. 1997 data excluded.

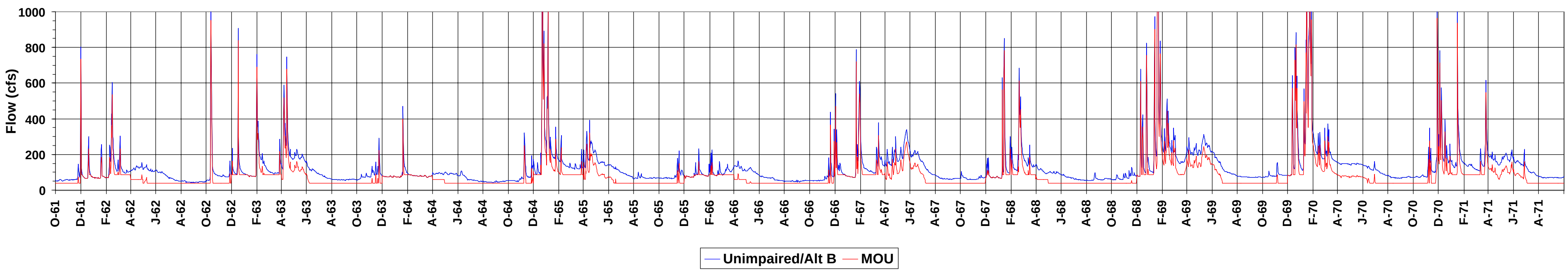
Figure H-1, Comparative Hydrographs

WY 1962-1971

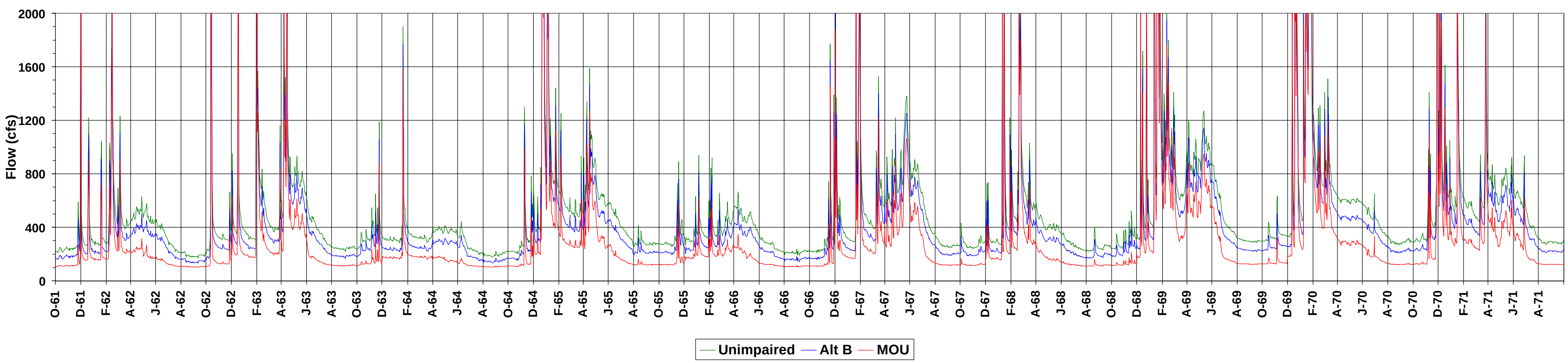
Eagle Canyon, North Fork Battle Creek



Inskip Reach, South Fork Battle Creek



Mainstem Battle Creek, Above Coleman PH

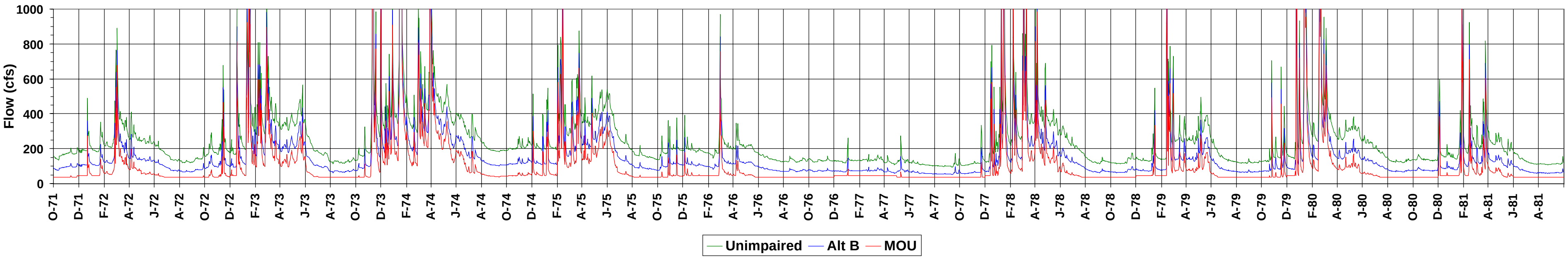


Flow data from modified RMI/Navigant daily flow model using USGS 11376550

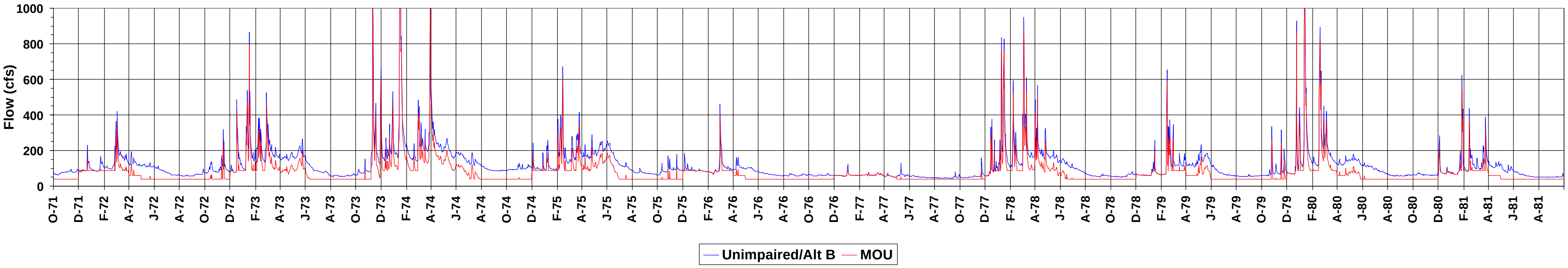
Figure H-2, Comparative Hydrographs

WY 1972-1981

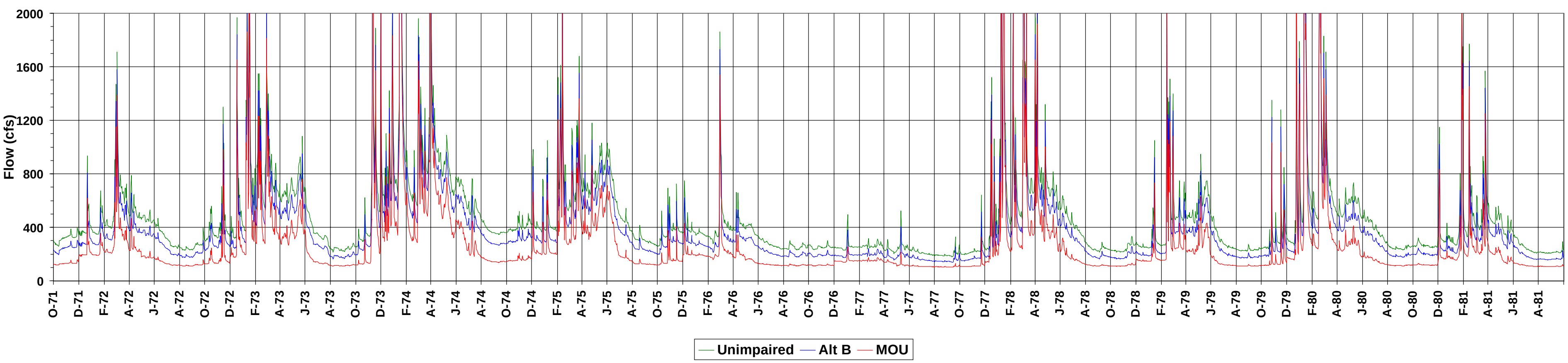
Eagle Canyon, North Fork Battle Creek



Inskip Reach, South Fork Battle Creek



Mainstem Battle Creek, Above Coleman PH

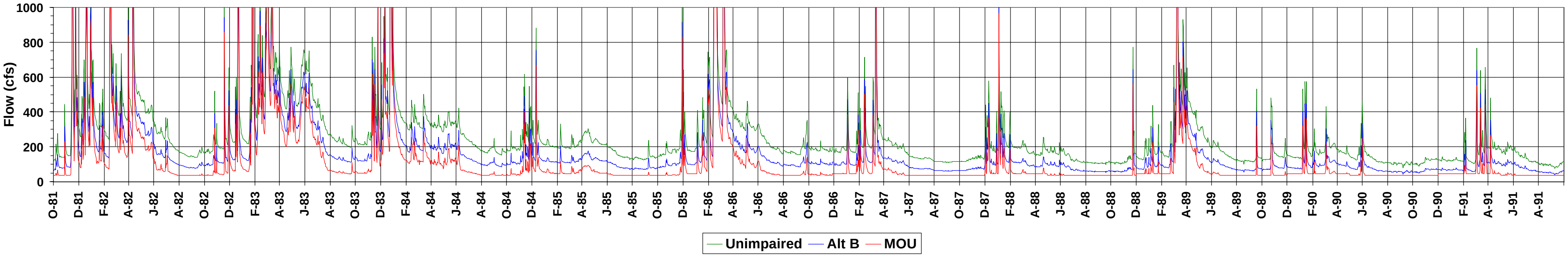


Flow data from modified RMI/Navigant daily flow model using USGS 11376550

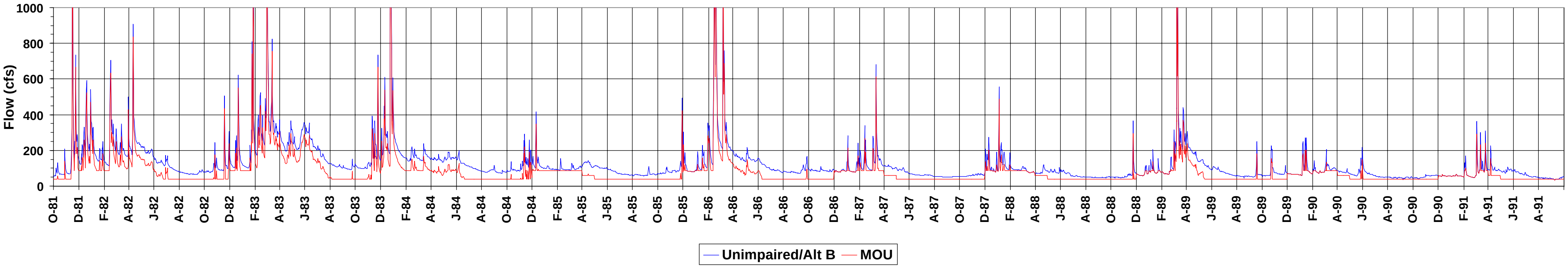
Figure H-3, Comparative Hydrographs

WY 1982-1991

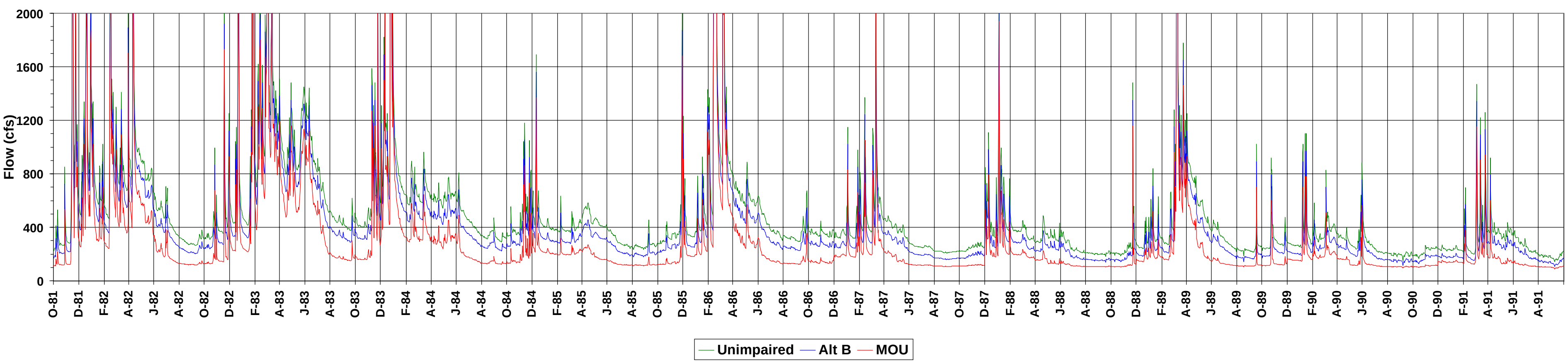
Eagle Canyon, North Fork Battle Creek



Inskip Reach, South Fork Battle Creek



Mainstem Battle Creek, Above Coleman PH

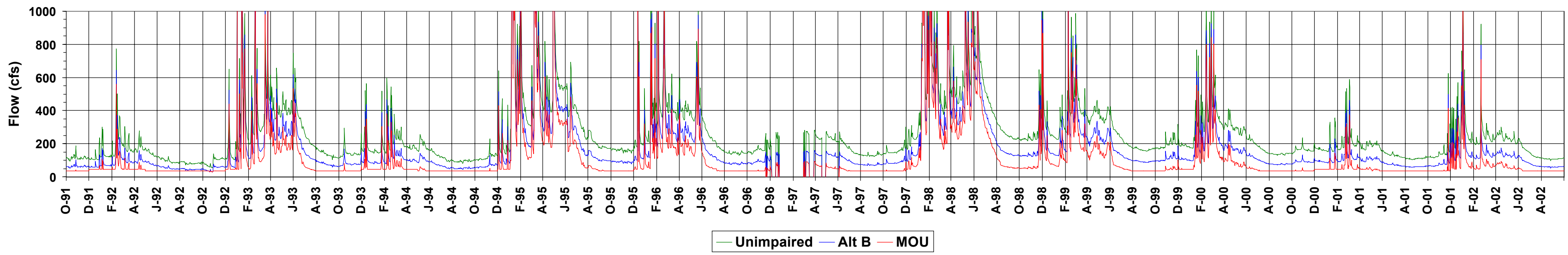


Flow data from modified RMI/Navigant daily flow model using USGS 11376550

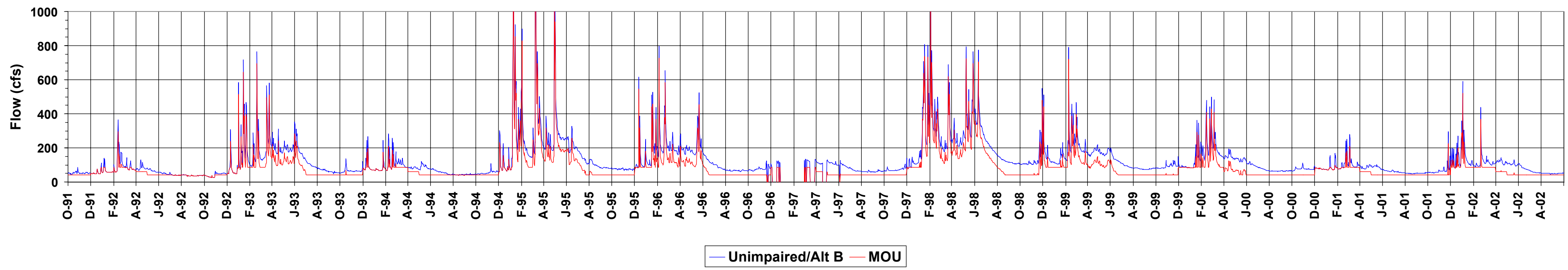
Figure H-4, Comparative Hydrographs

WY 1992-2002

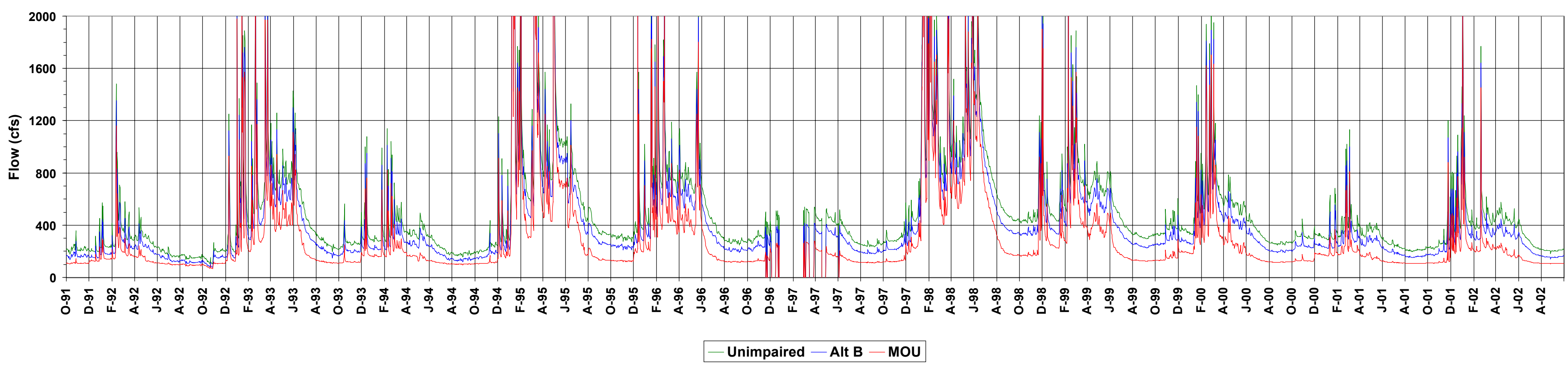
Eagle Canyon, North Fork Battle Creek



Inskip Reach, South Fork Battle Creek

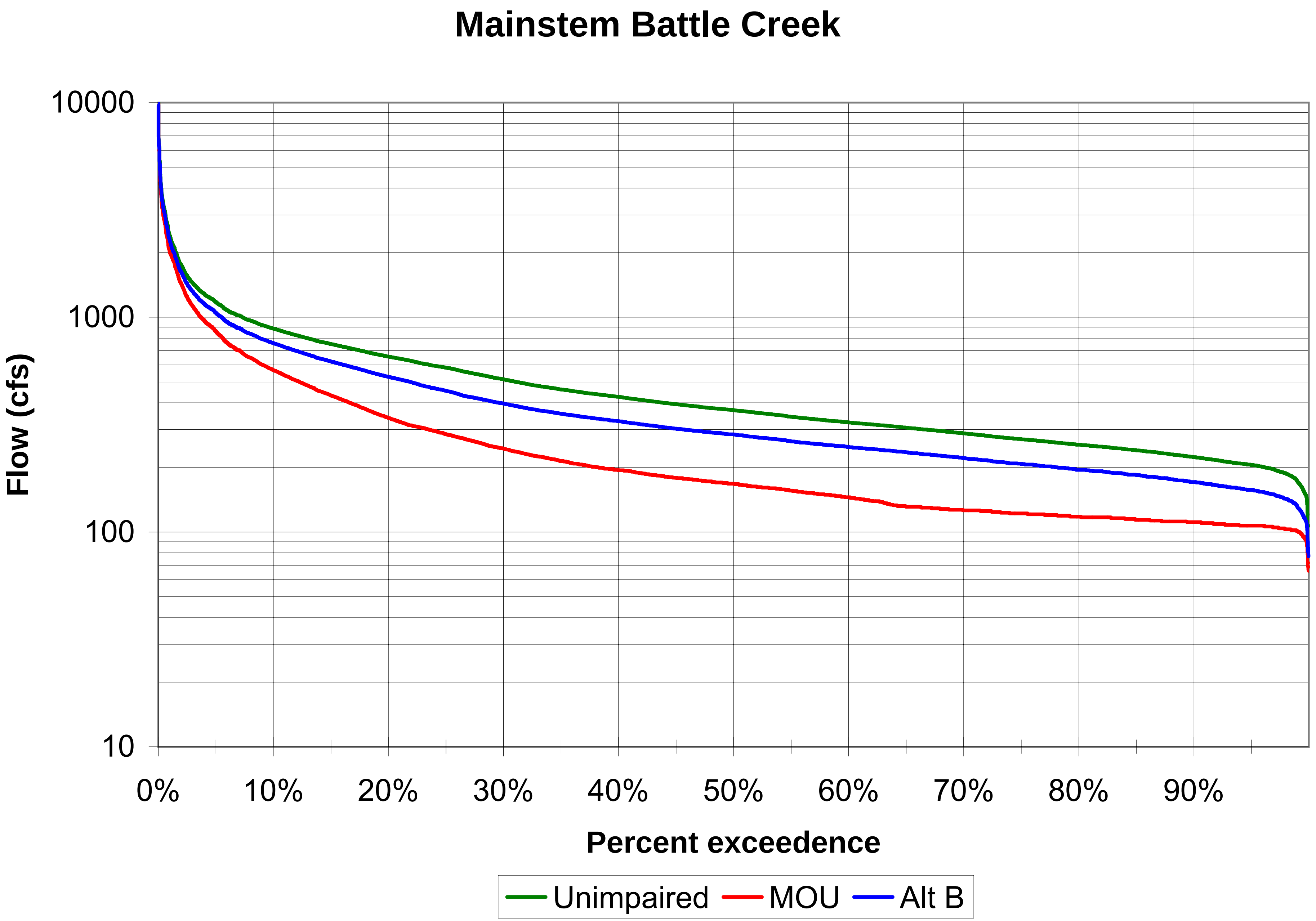


Mainstem Battle Creek, Above Coleman PH



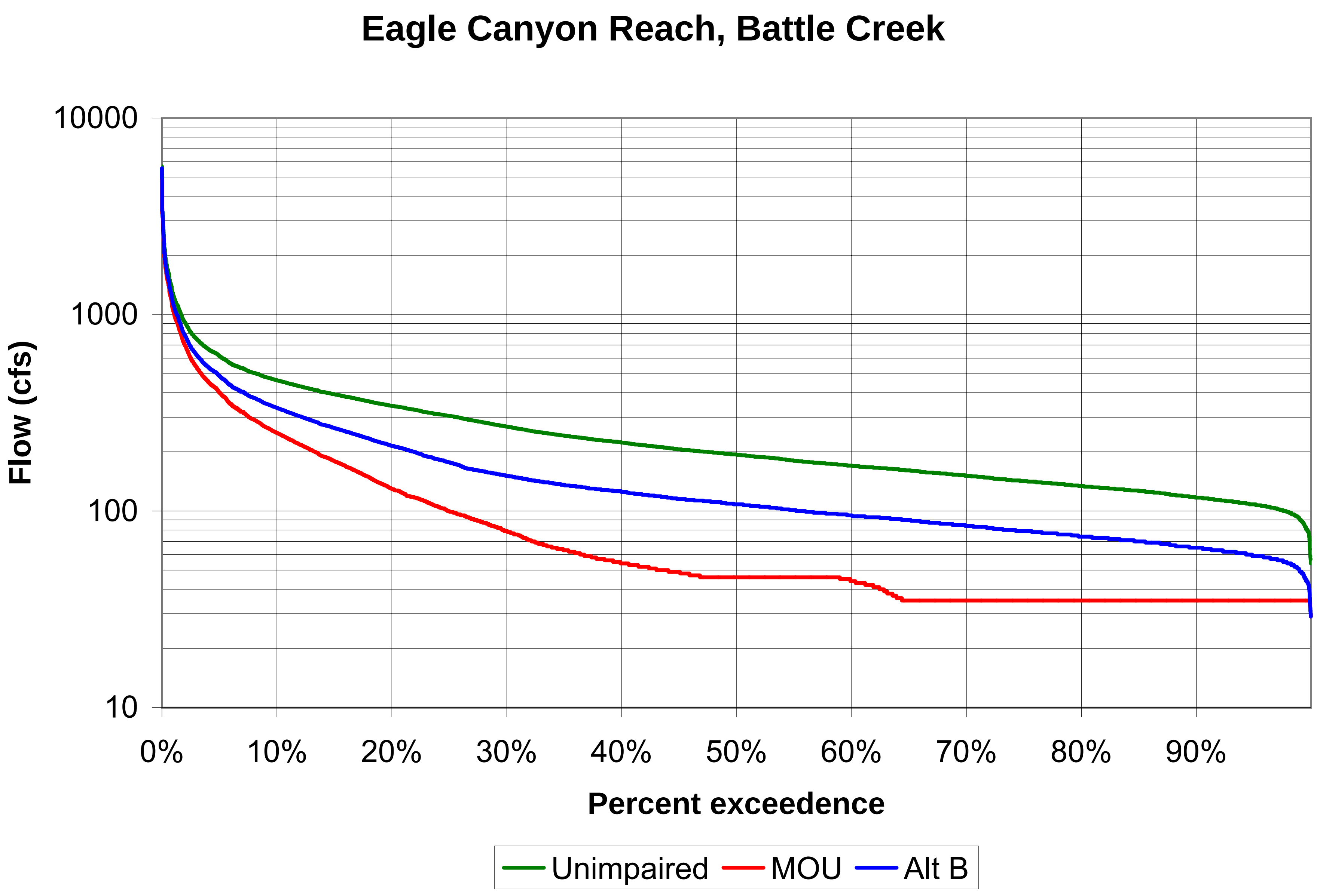
Flow data from modified RMI/Navigant daily flow model using USGS 11376550

Figure E-1. Flow Exceedence Curve, Mainstem Battle Creek



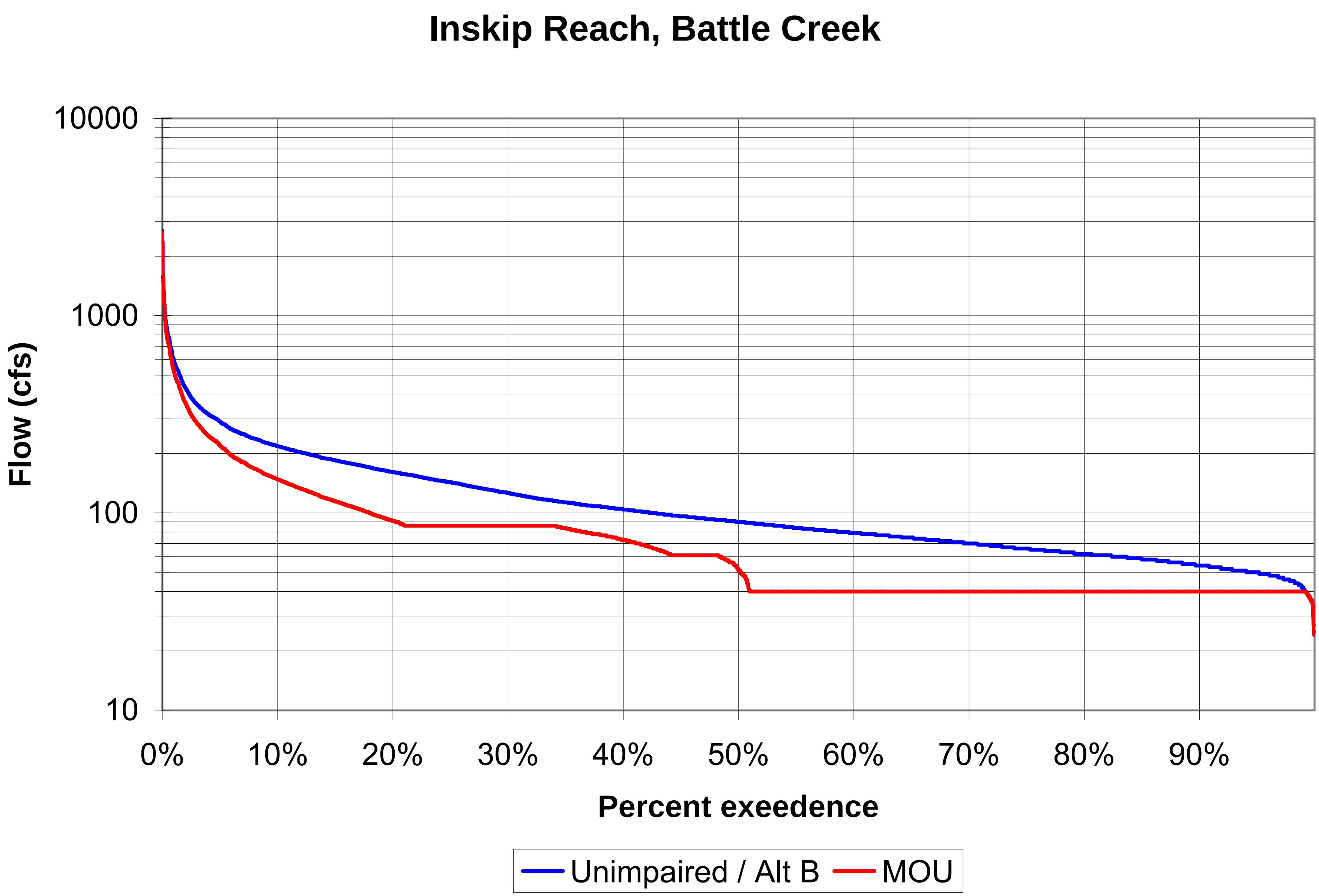
Water years 1962-2002, using daily flow model adopted from RMI/Navigant flow/econ model. 1997 data excluded.

Figure E-2, Flow Exceedence Curve, Eagle Canyon Reach, Battle Creek



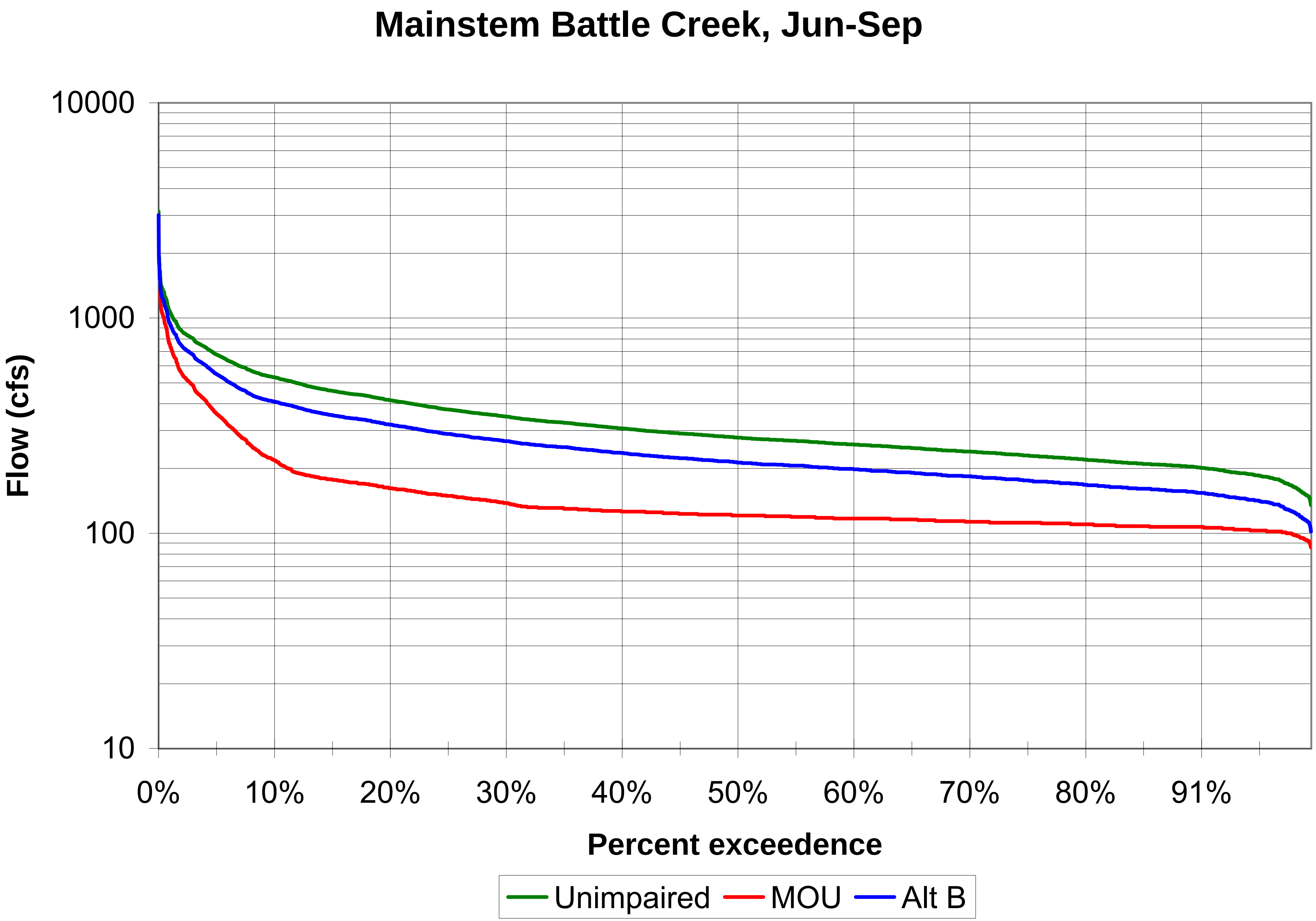
Water years 1962-2002, using daily flow model adopted from RMI/Navigant flow/econ model. 1997 data excluded.

Figure E-3, Flow Exceedence Curve, Inskip Reach, Battle Creek



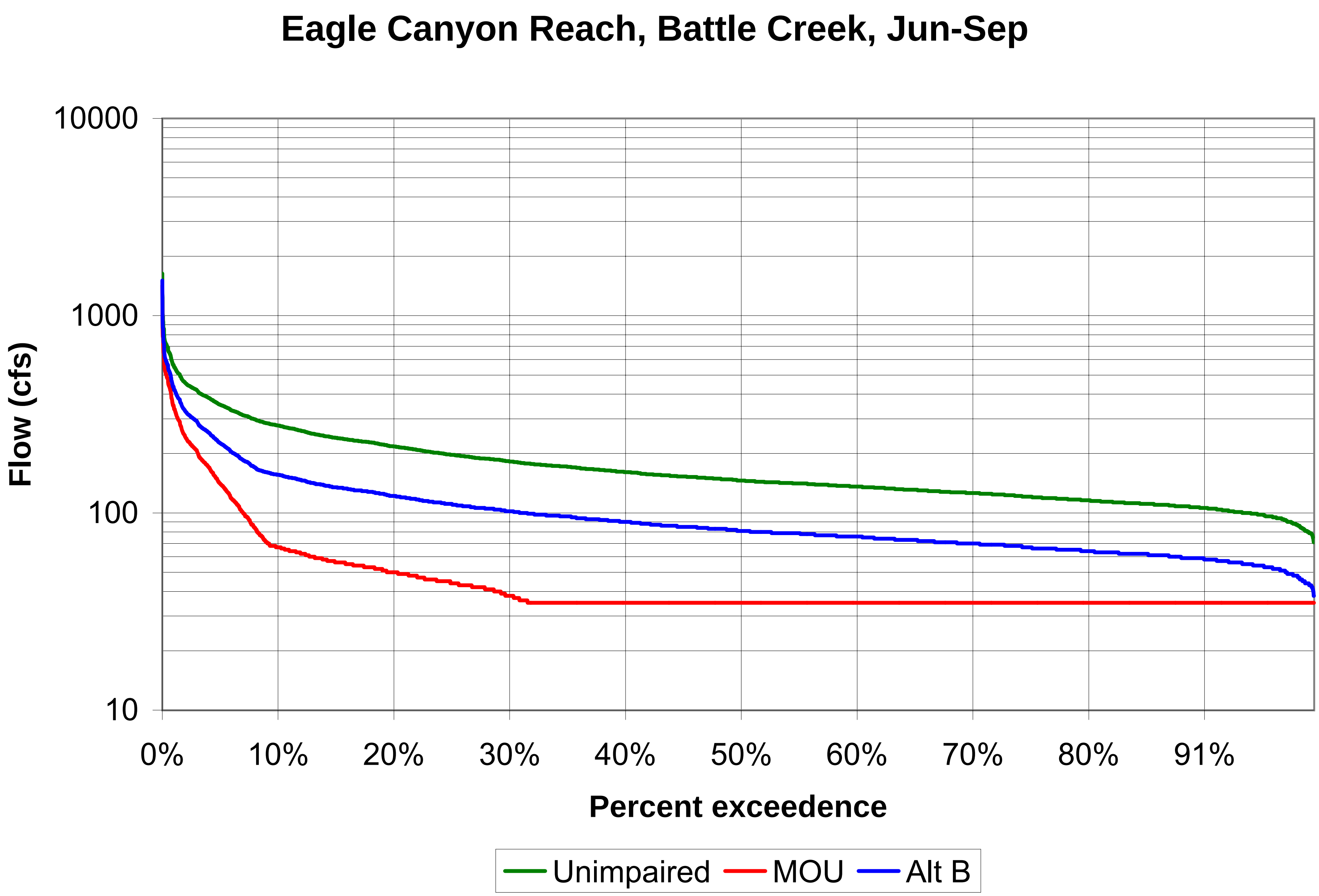
Water years 1962-2002, using daily flow model adopted from RMI/Navigant flow/econ model. 1997 data excluded.

Figure E-4. Flow Exceedence Curve, Mainstem Battle Creek, Summer



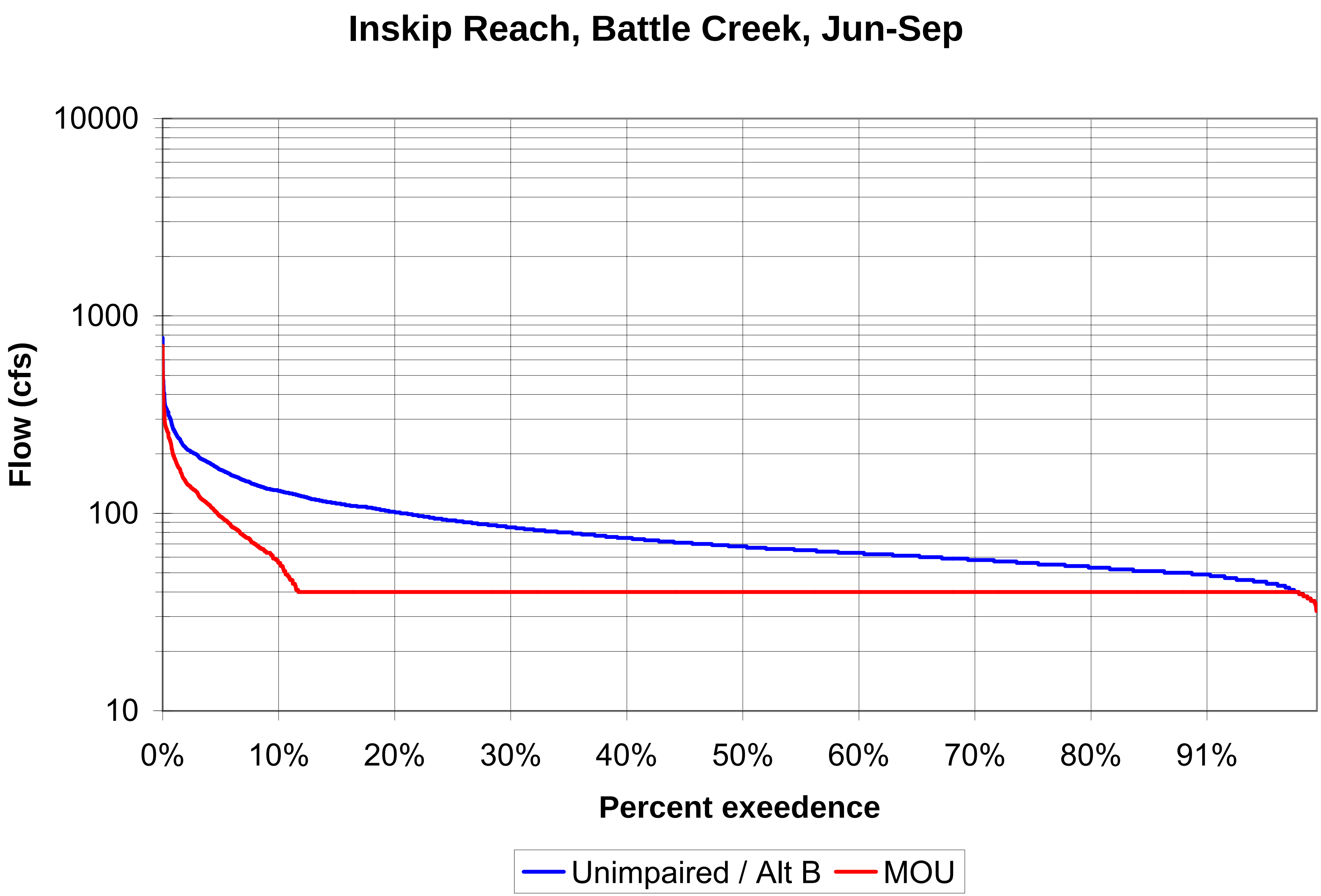
Water years 1962-2002, using daily flow model adopted from RMI/Navigant flow/econ model. 1997 data excluded.

Figure E-5, Flow Exceedence Curve, Eagle Canyon Reach, Summer



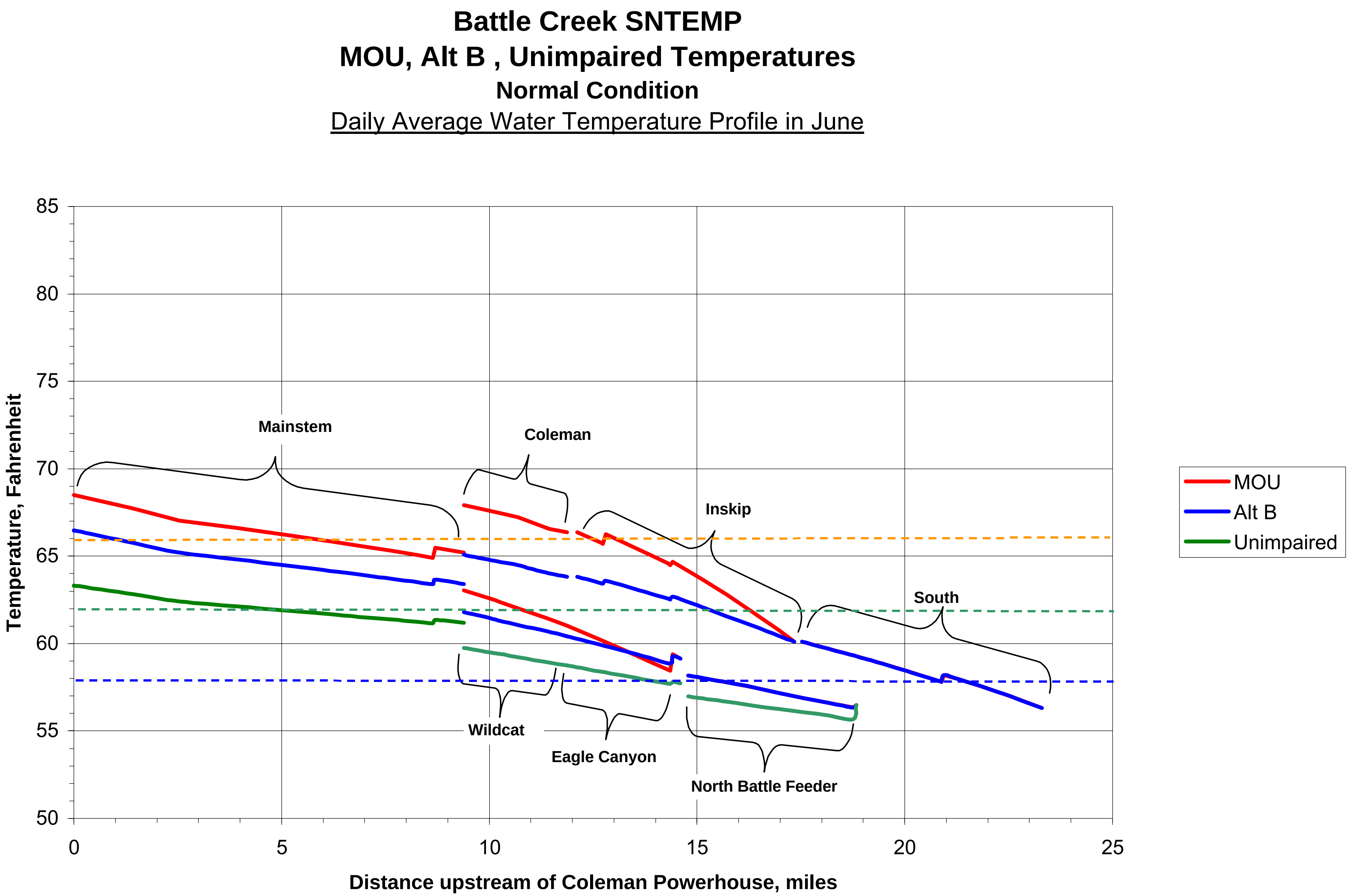
Water years 1962-2002, using daily flow model adopted from RMI/Navigant flow/econ model. 1997 data excluded.

Figure E-6, Flow Exceedence Curve, Inskip Reach, Summer



Water years 1962-2002, using daily flow model adopted from RMI/Navigant flow/econ model. 1997 data excluded.

Figure T-1, Avg-June

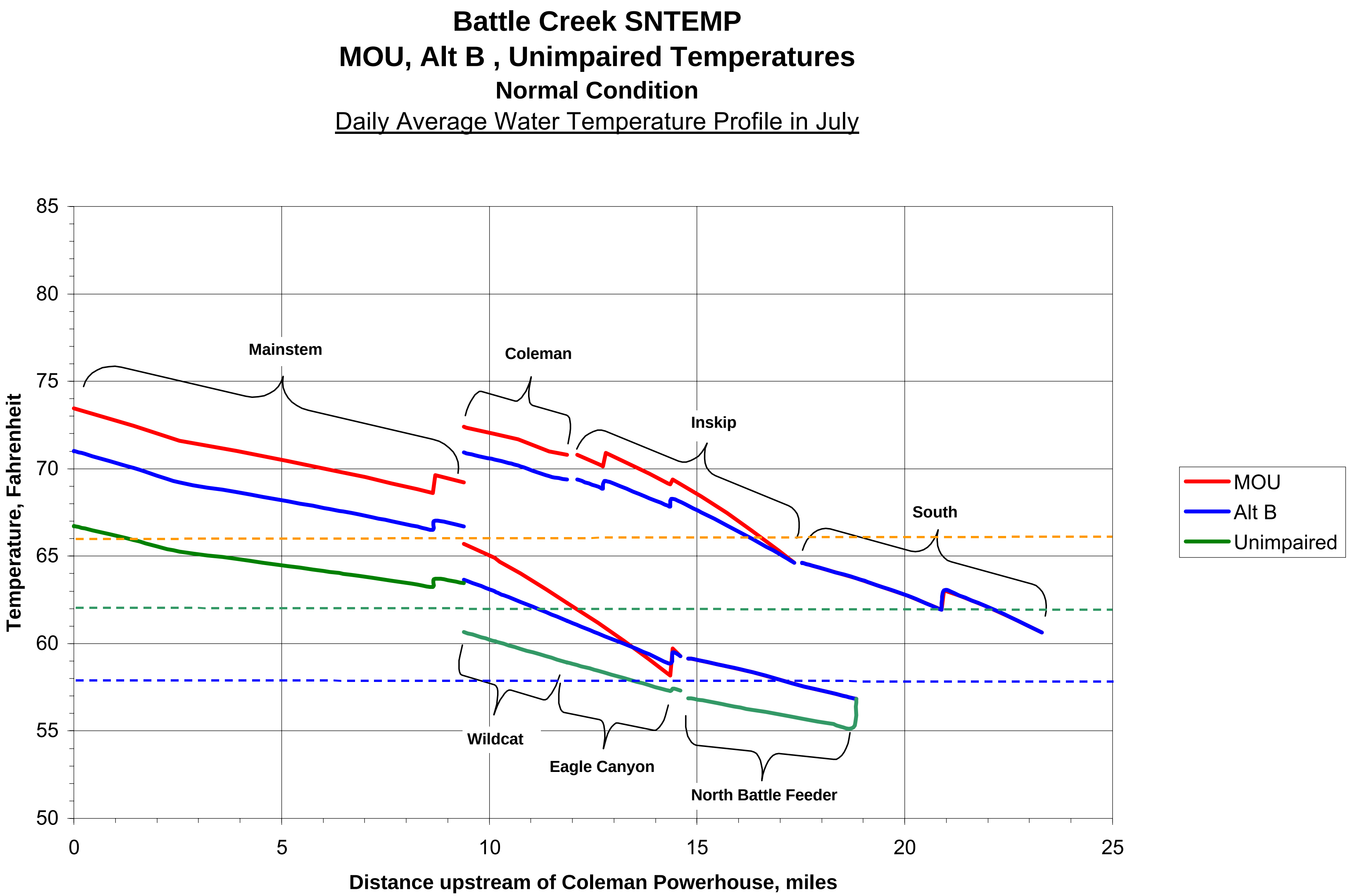


MOU Temp: SNTEMP Alt 3

Alt B Temp: North Fork and Mainstem, SNTEMP Alt 4; South Fork, SNTEMP Alt 6. **Alt B Mainstem does not account for SF cooling.**

Unimpaired: SNTEMP Alt 6 (no facilities below Volta)

Figure T-2, Avg-July

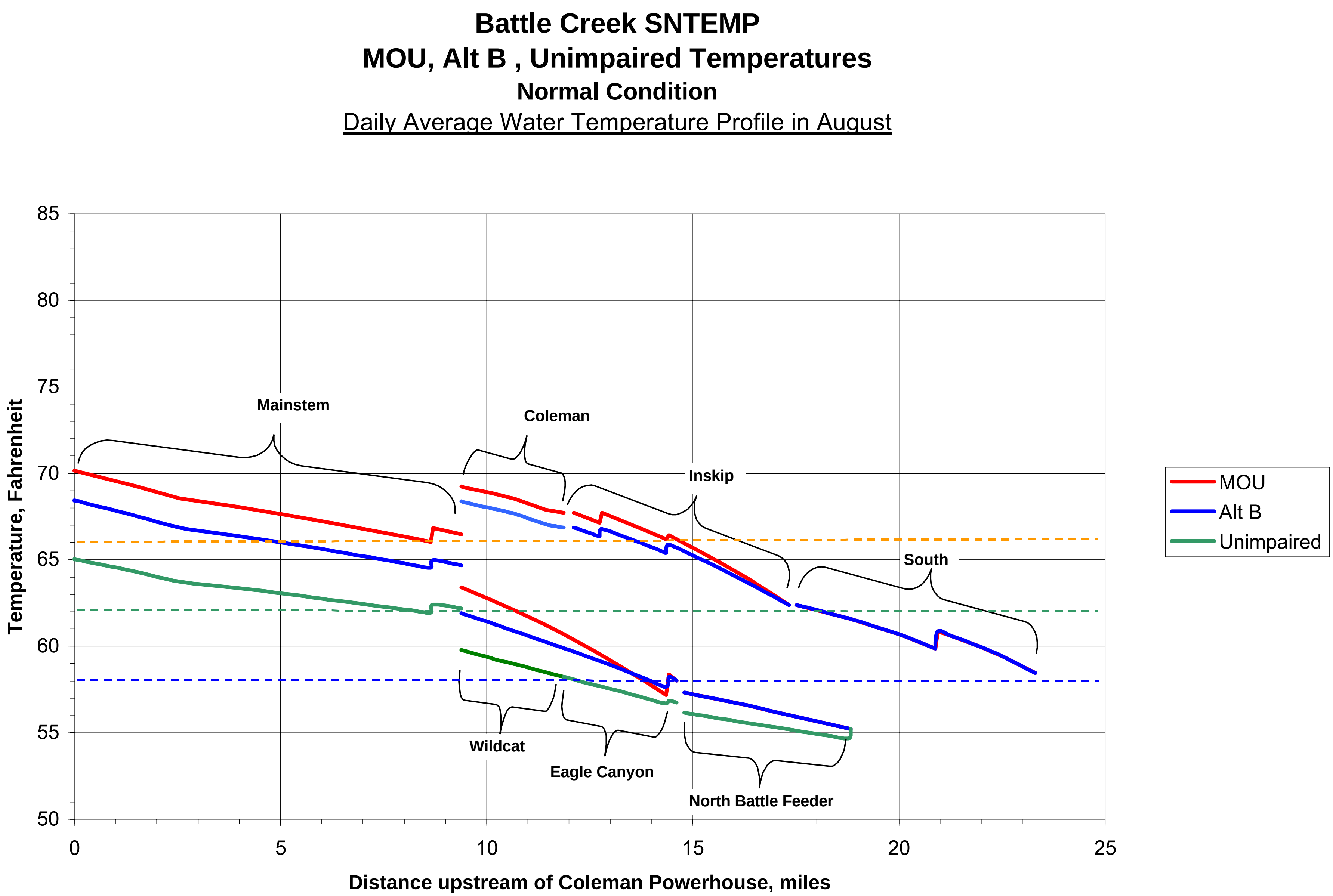


MOU Temp: SNTEMP Alt 3

Alt B Temp: North Fork and Mainstem, SNTEMP Alt 4; South Fork, SNTEMP Alt 6. **Alt B Mainstem does not account for SF cooling.**

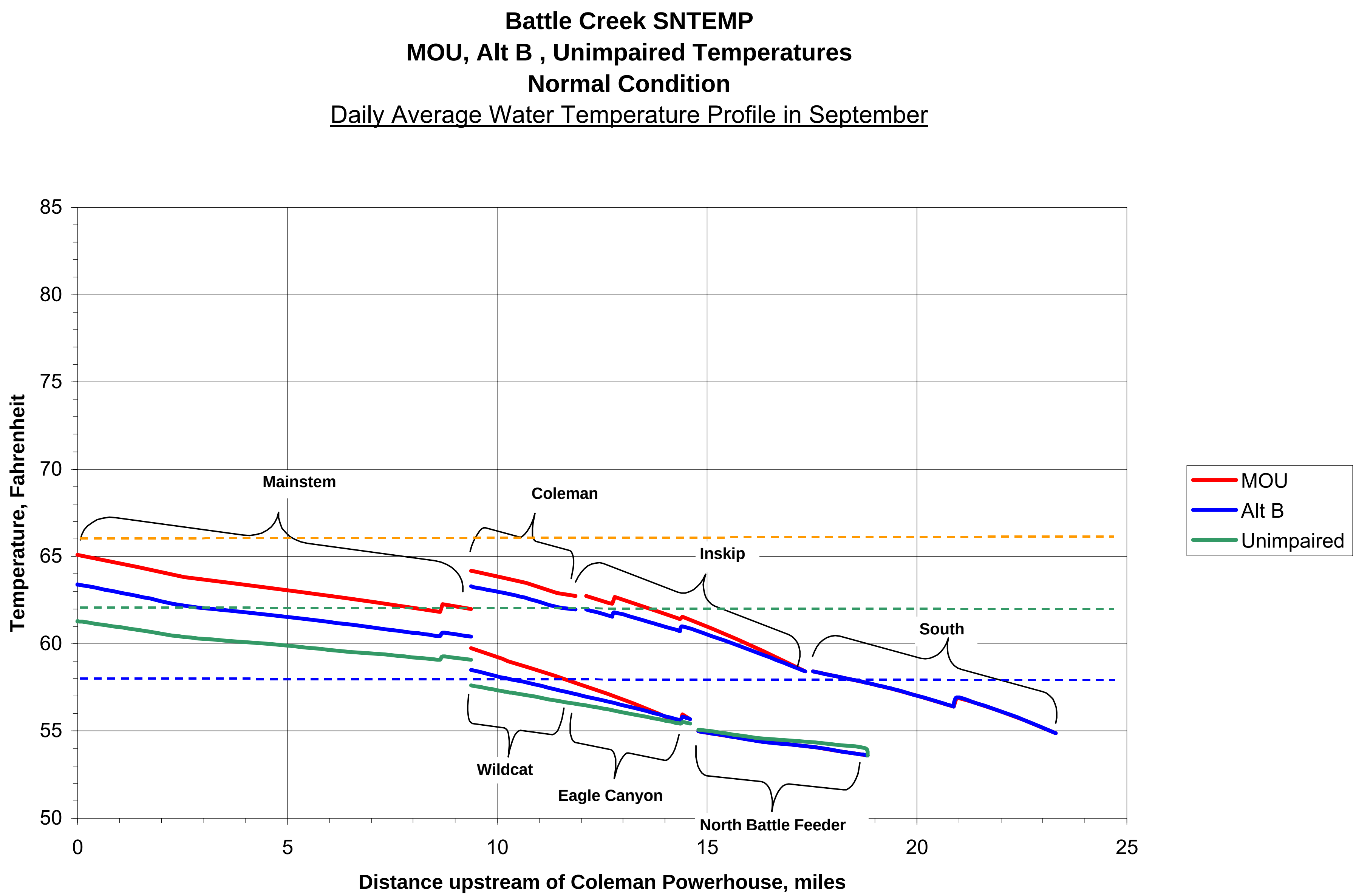
Unimpaired: SNTEMP Alt 6 (no facilities below Volta)

Figure T-3, Avg-Aug



MOU Temp: SNTEMP Alt 3
Alt B Temp: North Fork and Mainstem, SNTEMP Alt 4; South Fork, SNTEMP Alt 6. **Alt B Mainstem does not account for SF cooling.**
Unimpaired: SNTEMP Alt 6 (no facilities below Volta)

Figure T-4, Avg-Sep

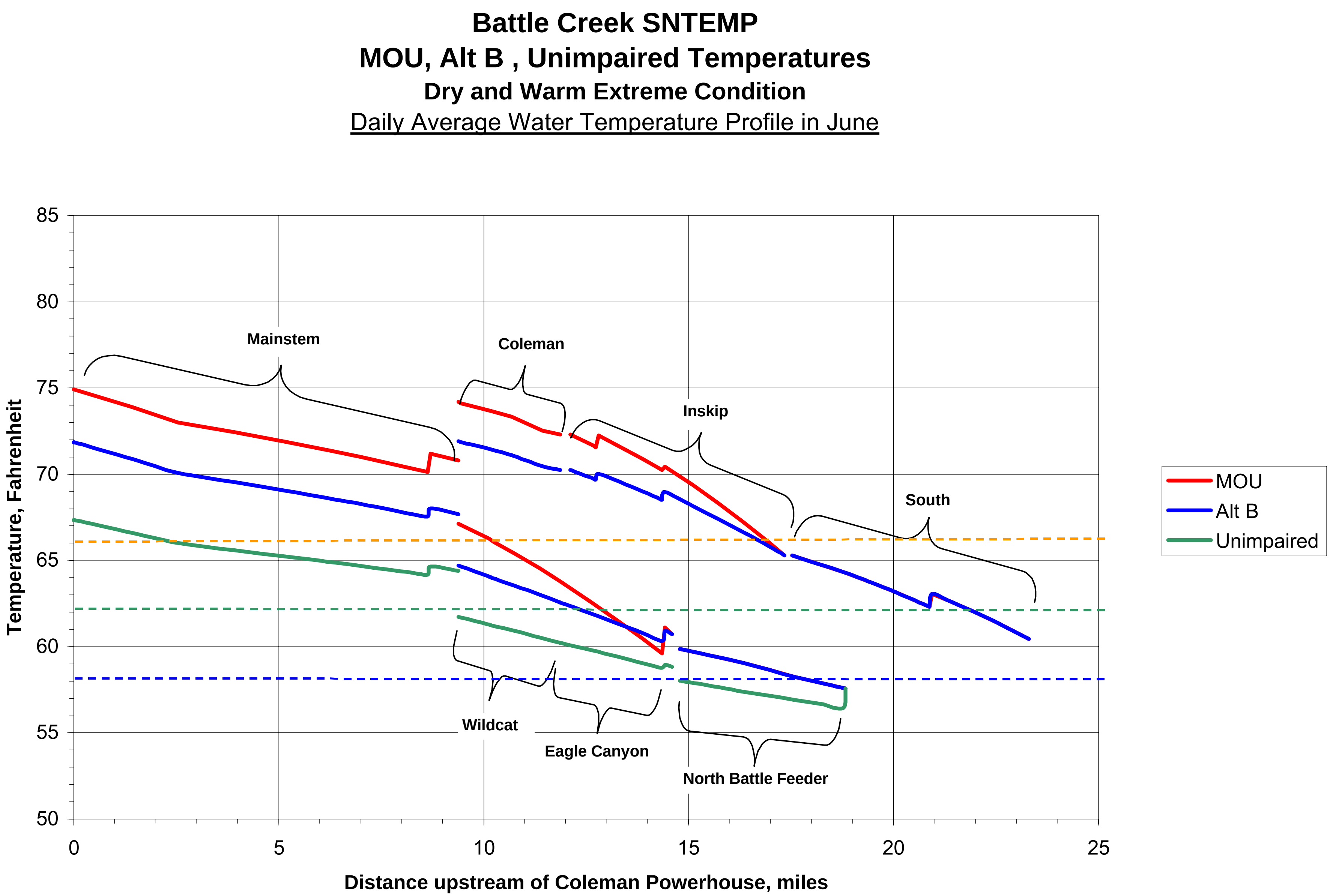


MOU Temp: SNTEMP Alt 3

Alt B Temp: North Fork and Mainstem, SNTEMP Alt 4; South Fork, SNTEMP Alt 6. **Alt B Mainstem does not account for SF cooling.**

Unimpaired: SNTEMP Alt 6 (no facilities below Volta)

Figure T-5, DryWarm-June

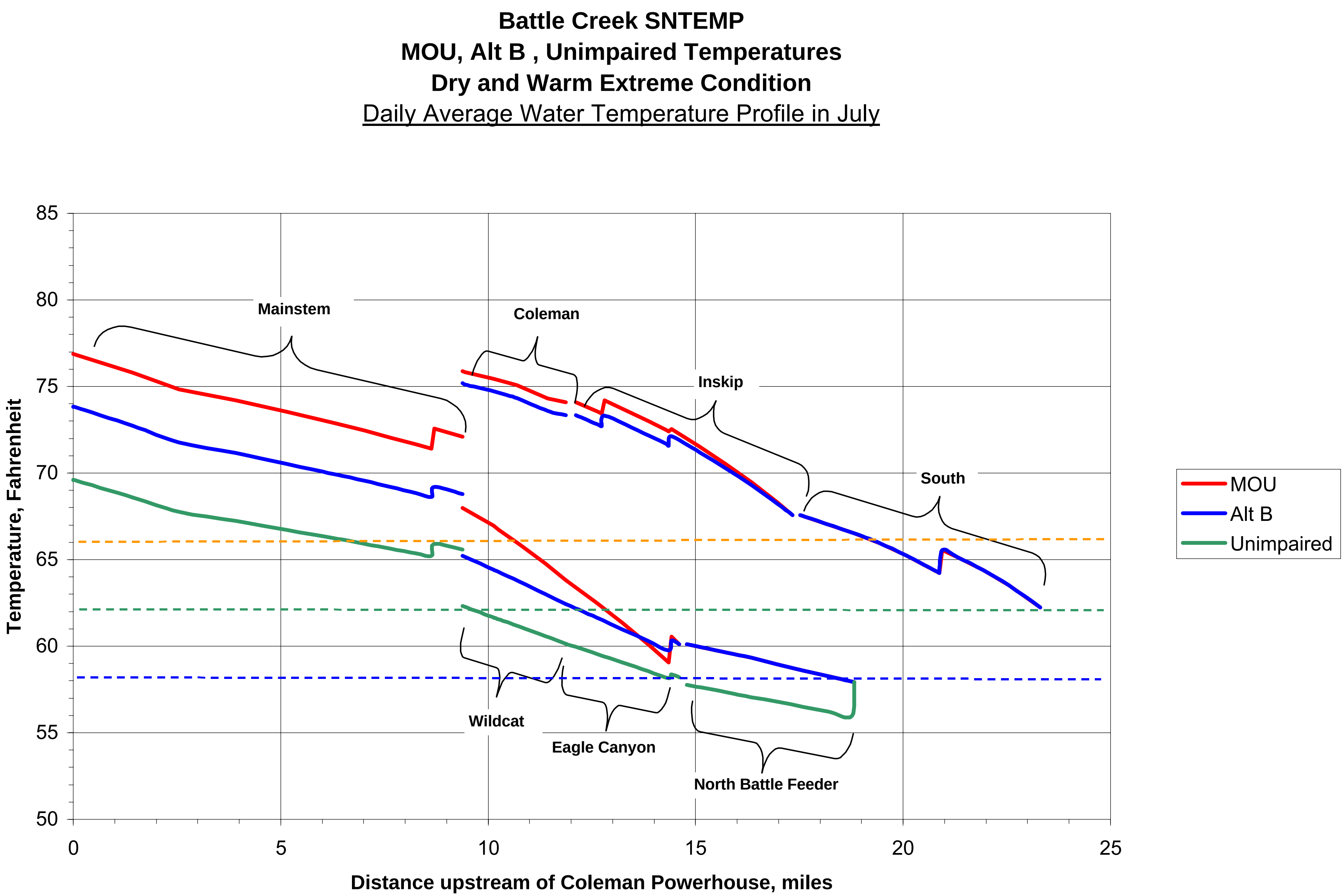


MOU Temp: SNTEMP Alt 3

Alt B Temp: North Fork and Mainstem, SNTEMP Alt 4; South Fork, SNTEMP Alt 6. **Alt B Mainstem does not account for SF cooling.**

Unimpaired: SNTEMP Alt 6 (no facilities below Volta)

Figure T-6, DryWarm-July

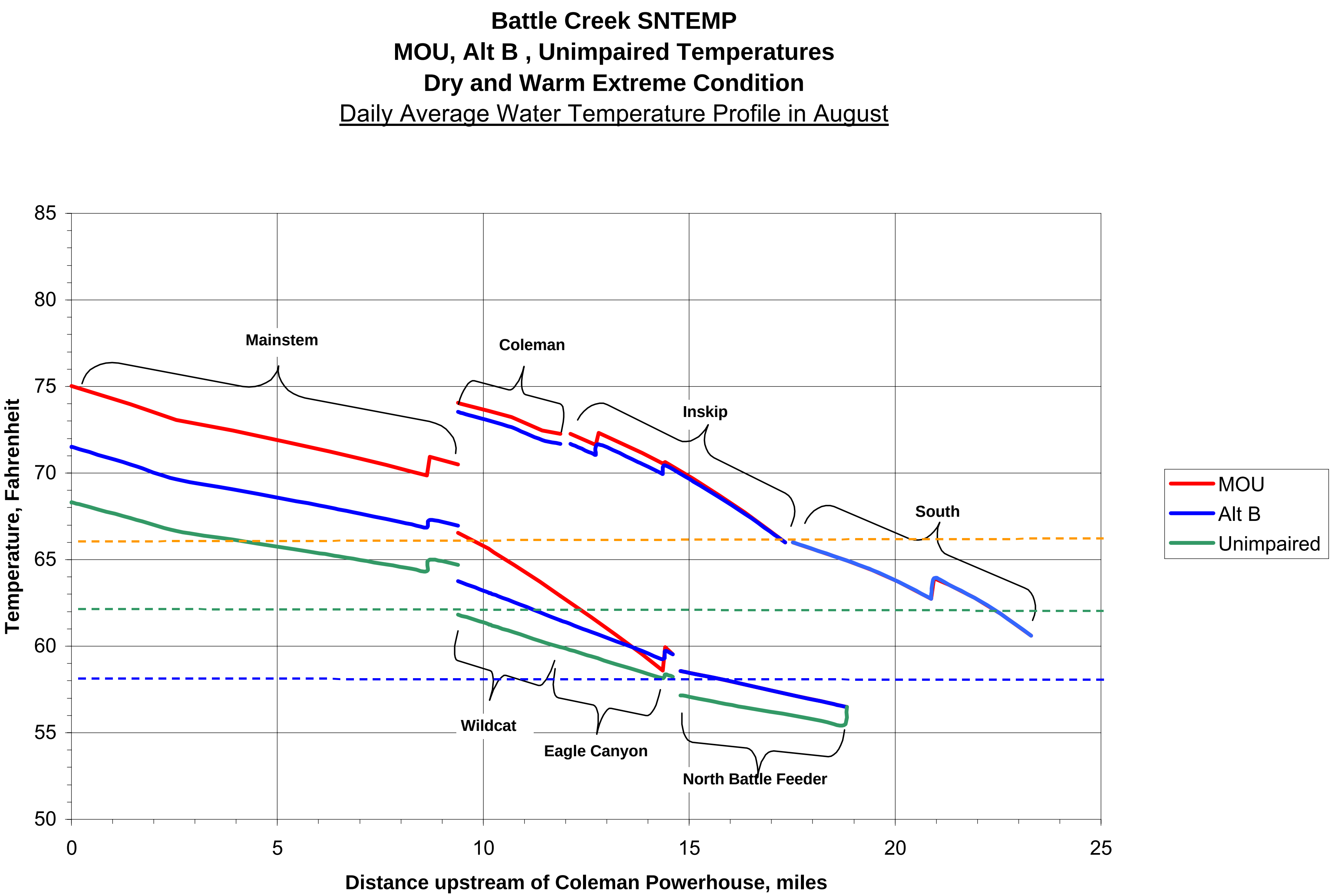


MOU Temp: SNTEMP Alt 3

Alt B Temp: North Fork and Mainstem, SNTEMP Alt 4; South Fork, SNTEMP Alt 6. **Alt B Mainstem does not account for SF cooling.**

Unimpaired: SNTEMP Alt 6 (no facilities below Volta)

Figure T-7, DryWarm-Aug

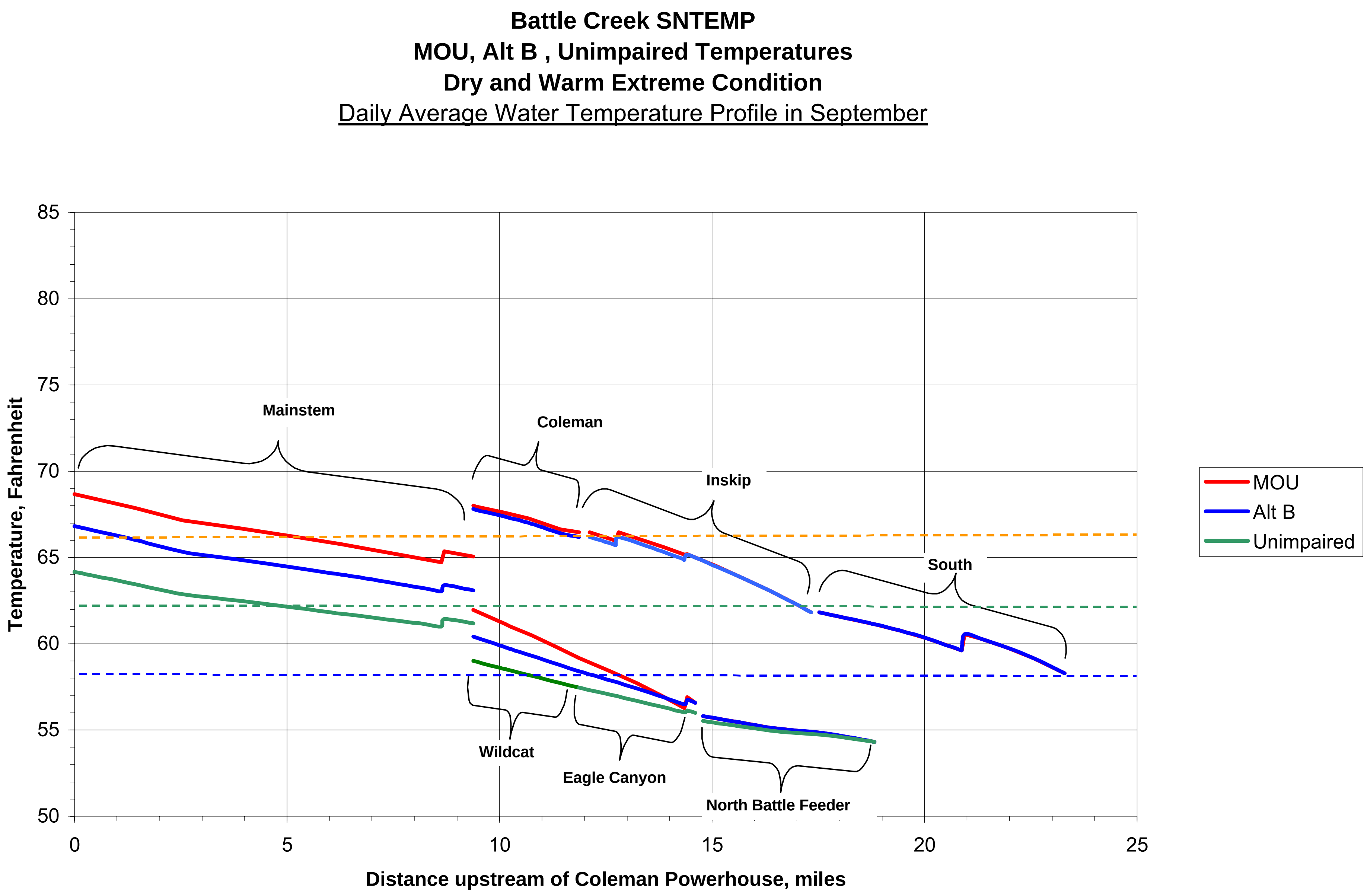


MOU Temp: SNTEMP Alt 3

Alt B Temp: North Fork and Mainstem, SNTEMP Alt 4; South Fork, SNTEMP Alt 6. **Alt B Mainstem does not account for SF cooling.**

Unimpaired: SNTEMP Alt 6 (no facilities below Volta)

Figure T-8, DryWarm-Sep



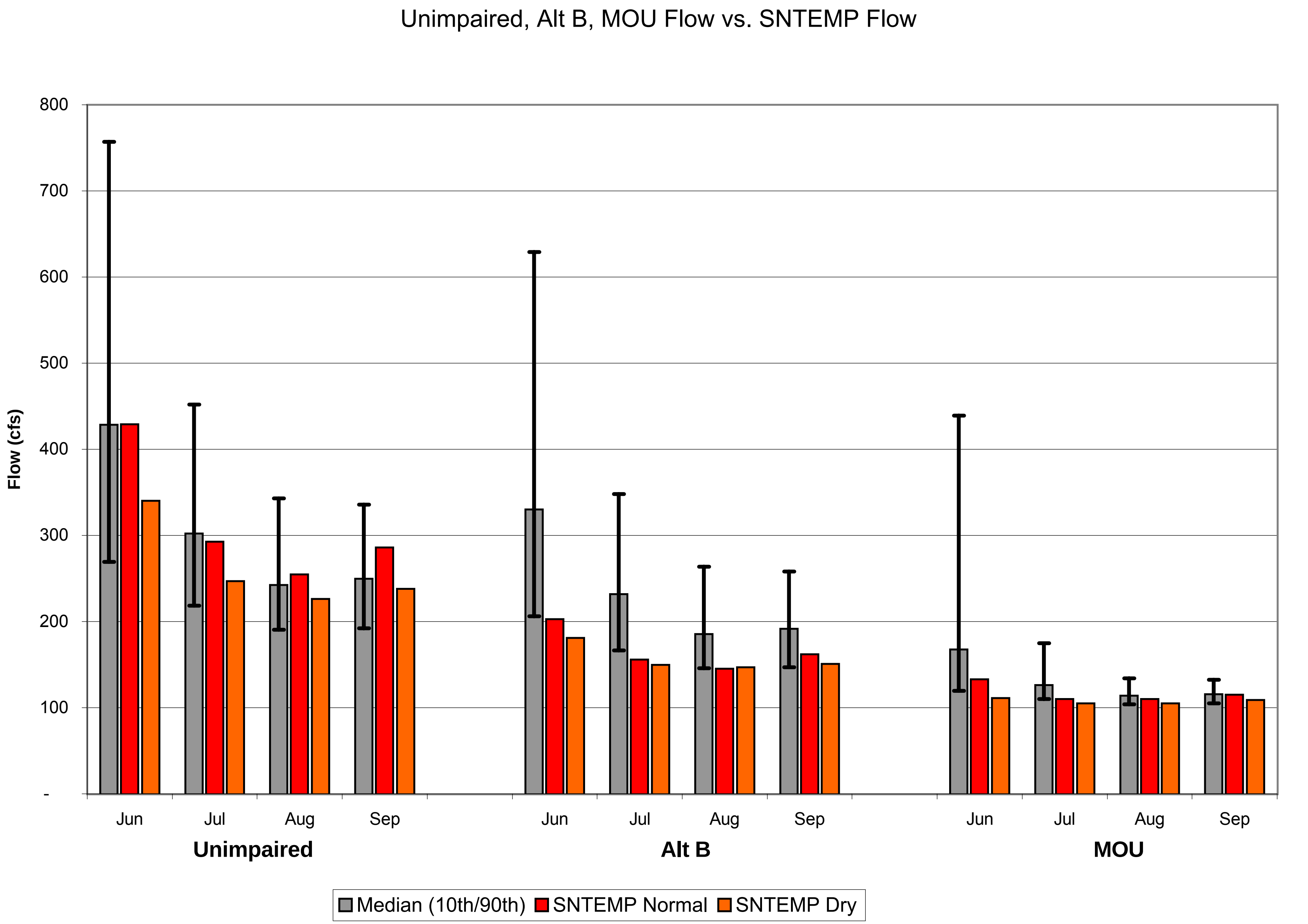
MOU Temp: SNTEMP Alt 3

Alt B Temp: North Fork and Mainstem, SNTEMP Alt 4; South Fork, SNTEMP Alt 6. **Alt B Mainstem does not account for SF cooling.**

Unimpaired: SNTEMP Alt 6 (no facilities below Volta)

Figure C-1, SNTEMP Flow Comparison

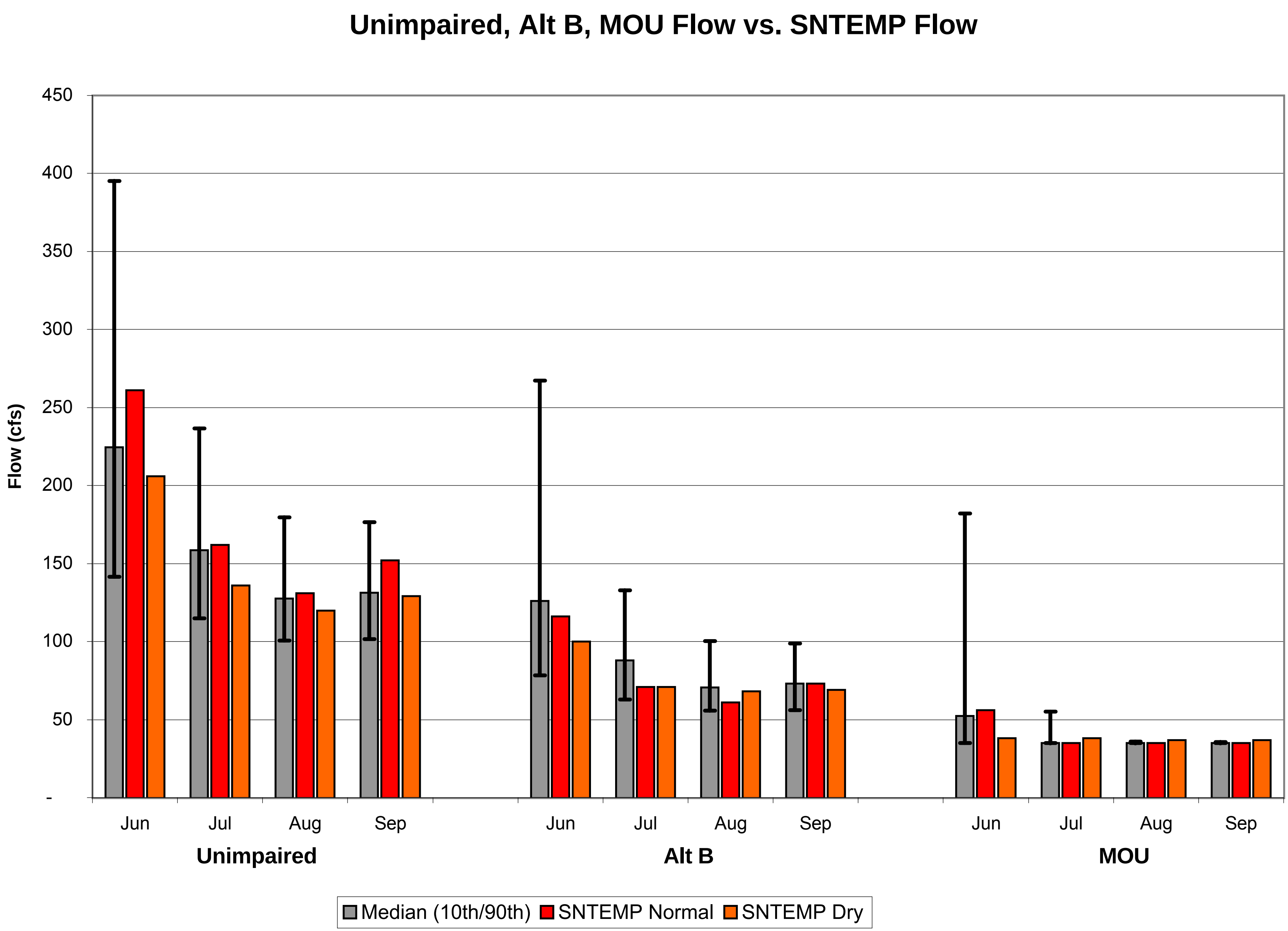
Battle Creek Mainstem



WY 1962-2002 median monthly flows plus 10th and 90th percentile range for Unimpaired, Alt B, MOU: RMI/Navigant flow model. SNTEMP normal and dry flows from Scott Tu, PG&E.

Figure C-2, SNTEMP Flow Comparsion

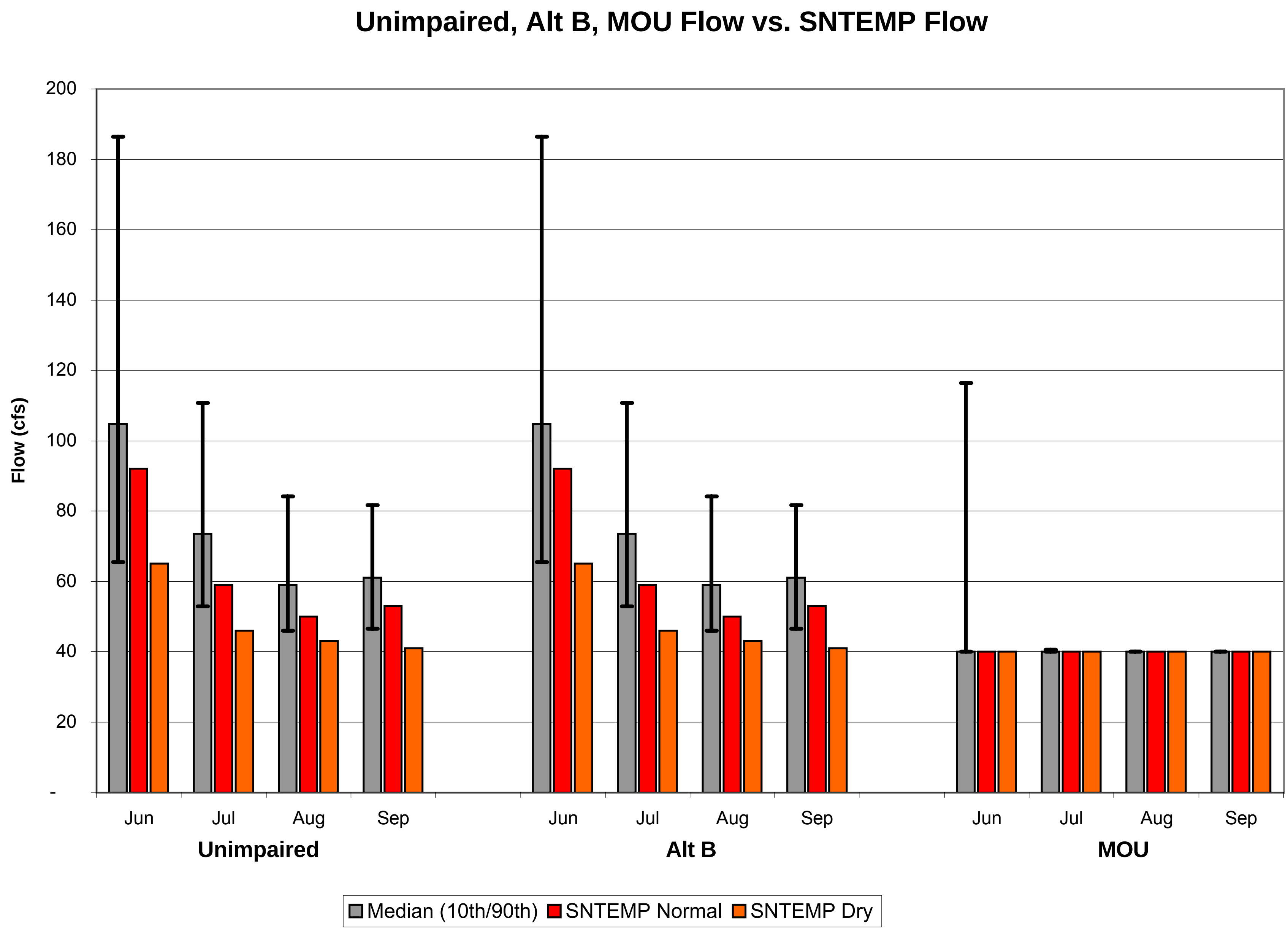
Battle Creek, Eagle Canyon Reach



WY 1962-2002 median monthly flows plus 10th and 90th percentile range for Unimpaired, Alt B, MOU: RMI/Navigant flow model. SNTEMP normal and dry flows from Scott Tu, PG&E.

Figure C-3, SNTEMP Flow Comparison

Battle Creek, Inskip Reach



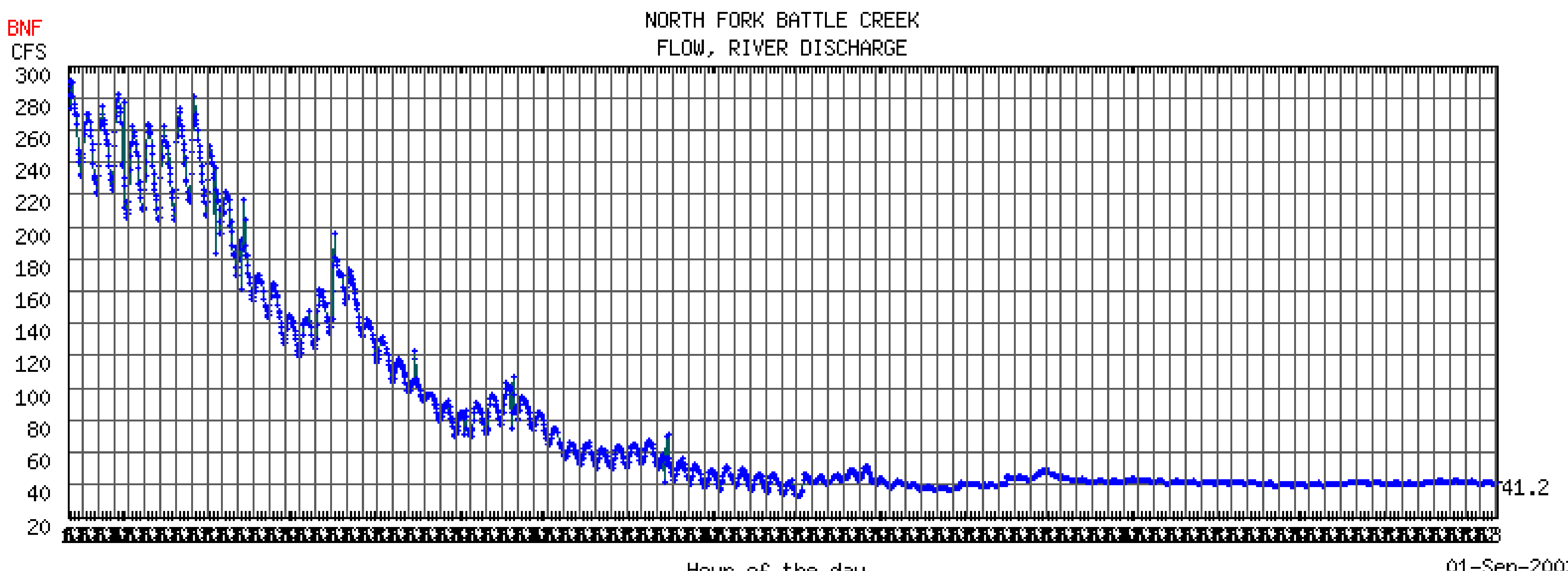
WY 1962-2002 median monthly flows plus 10th and 90th percentile range for Unimpaired, Alt B, MOU: RMI/Navigant flow model. SNTEMP normal and dry flows from Scott Tu, PG&E.

Figure I-1. North Fork Battle Creek Fish Barrier Flow

NORTH FORK BATTLE CREEK *(BNF)*

Elevation: 998' · SACRAMENTO R basin · Operator: CA Dept of Water Resources
Sensor ID number *9484*

Plot generated Wednesday at 12:32:12



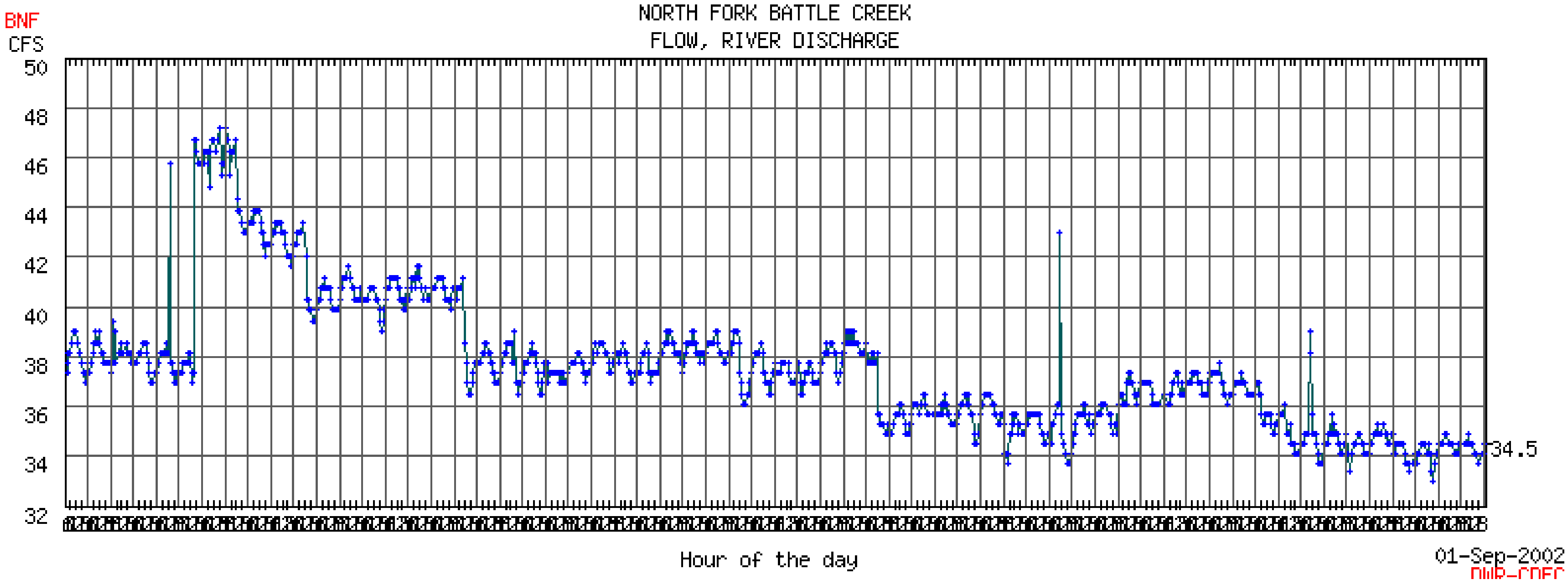
Data from 06/01/2003 00:00 through 09/01/2003 00:00 · Duration: 92days
Max of period: 291 · Min of period: 32.6

Figure I-2. North Fork Battle Creek Fish Barrier Flow

NORTH FORK BATTLE CREEK *(BNF)*

Elevation: 998' · SACRAMENTO R basin · Operator: CA Dept of Water Resources
Sensor ID number *9484*

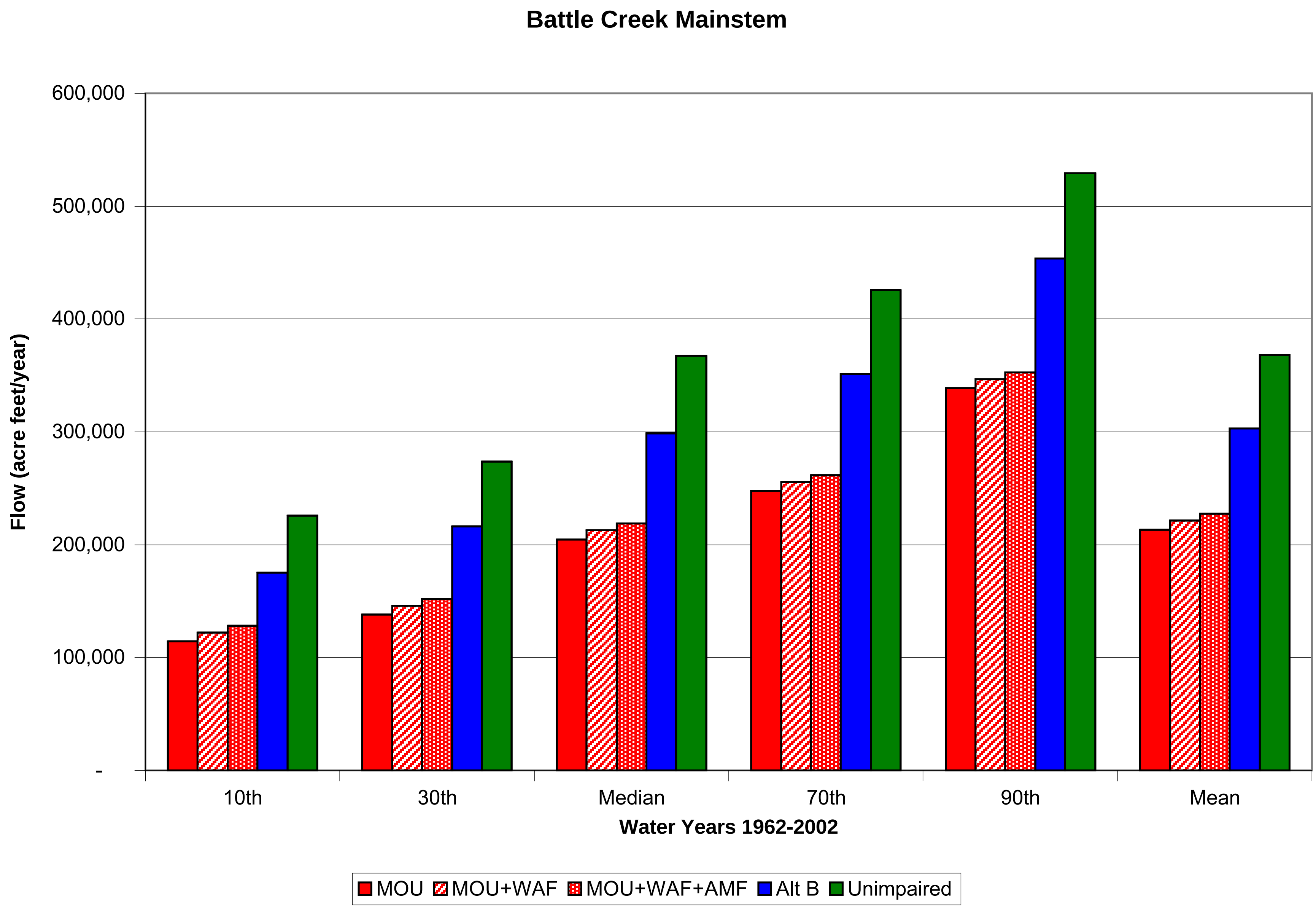
Plot generated Wednesday at 12:50:23



Data from 06/01/2002 00:00 through 09/01/2002 00:00 · Duration: 92days
Max of period: 47.18 · Min of period: 32.98

Figure A-1, Annual Acre Feet

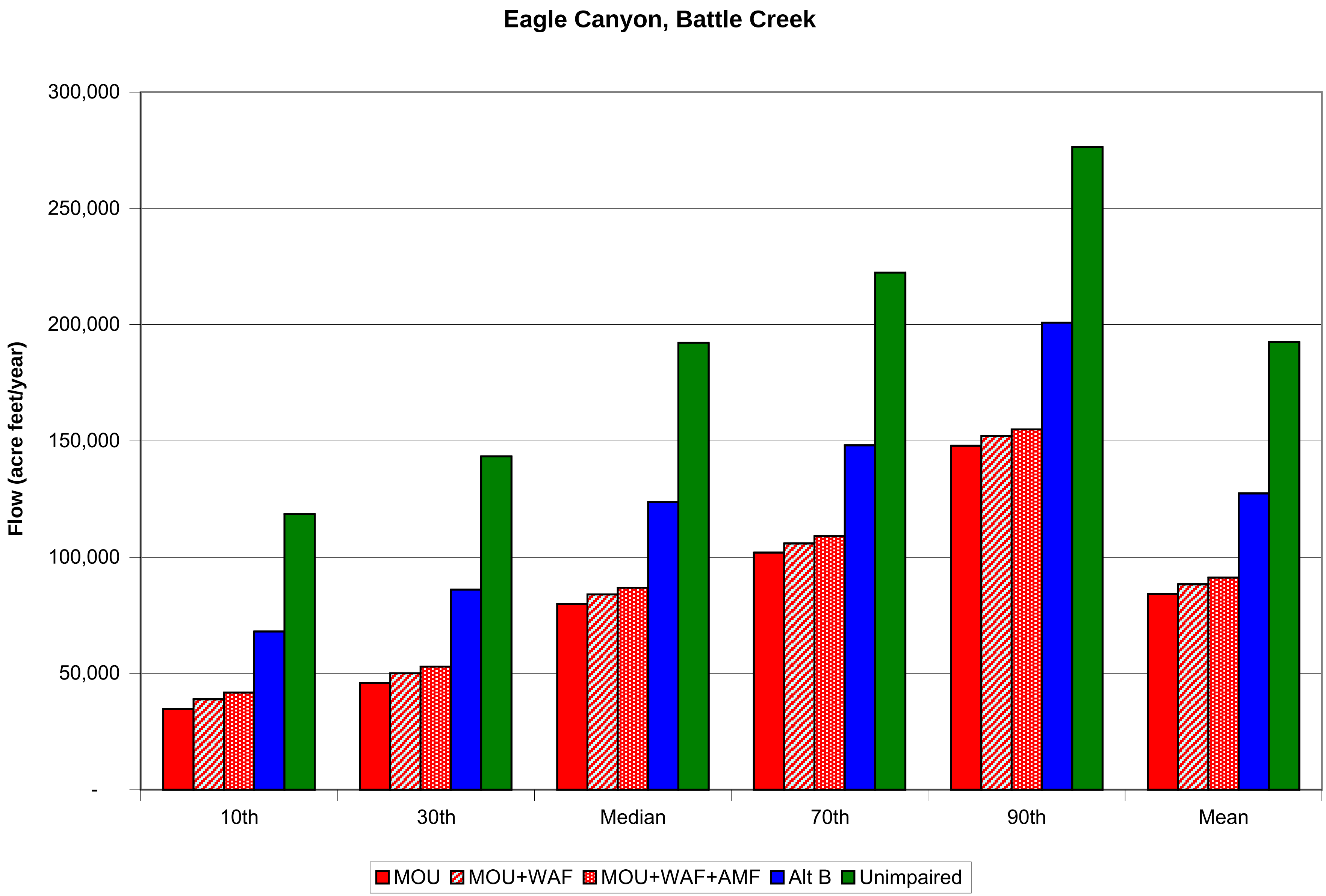
Acre Feet/Year Comparison



1962-2002 annual flows derived from modified RVI/Navigant model. 10% - 90% and mean annual flows shown. WAF ($3 mil): ~8000 AF. AMF ($3 mil): ~6000 AF. $50/mWh, 2.5% inflation, 9.53% discount rate, no purchase until 2014.

Figure A-2, Annual Acre Feet

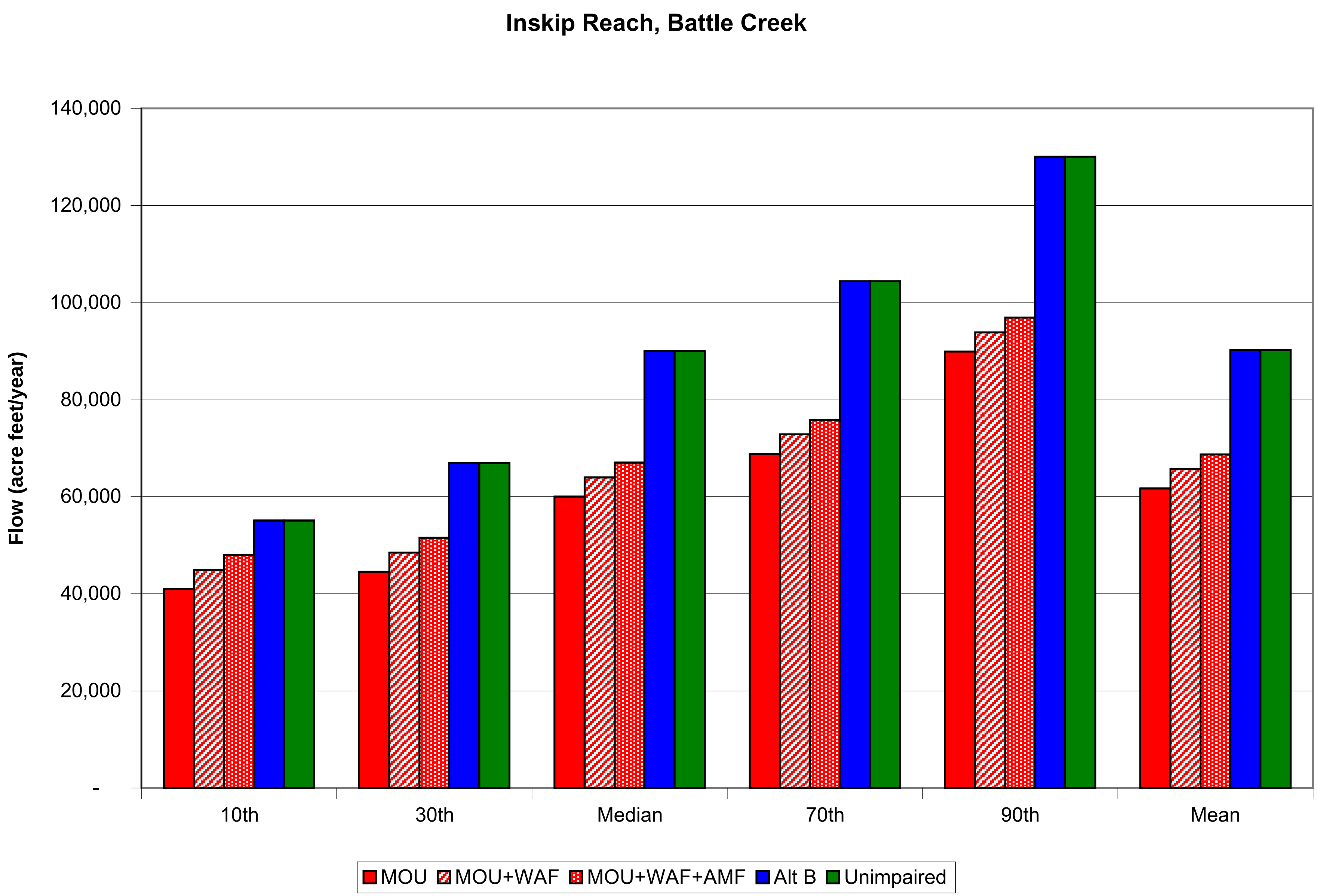
Acre Feet/Year Comparison



1962-2002 annual flows derived from modified RVI/Navigant model. 10% - 90% and mean annual flows shown. WAF ($1.5 mil): ~4000 AF. AMF ($1.5 mil): ~3000 AF. $50/mWh, 2.5% inflation, 9.53% discount rate, no purchase until 2014, equal NF/SF.

Figure A-3, Annual Acre Feet

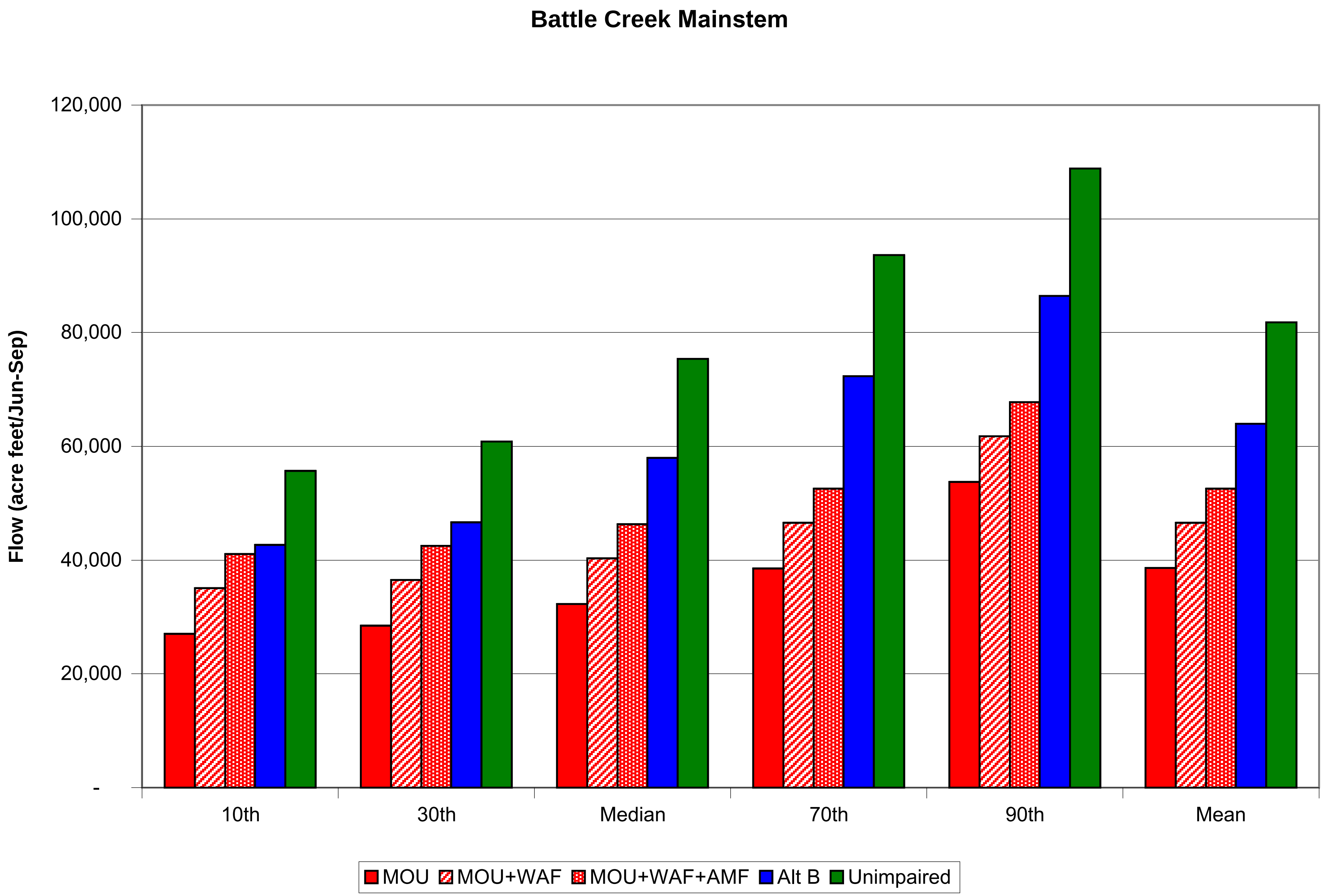
Acre Feet/Year Comparison



1962-2002 annual flows derived from modified RVI/Navigant model. 10% - 90% and mean annual flows shown. WAF ($1.5 mil): ~4000 AF. AMF ($1.5 mil): ~3000 AF. $50/mWh, 2.5% inflation, 9.53% discount rate, no purchase until 2014, equal NF/SF.

Figure A-4, Summer Acre Feet

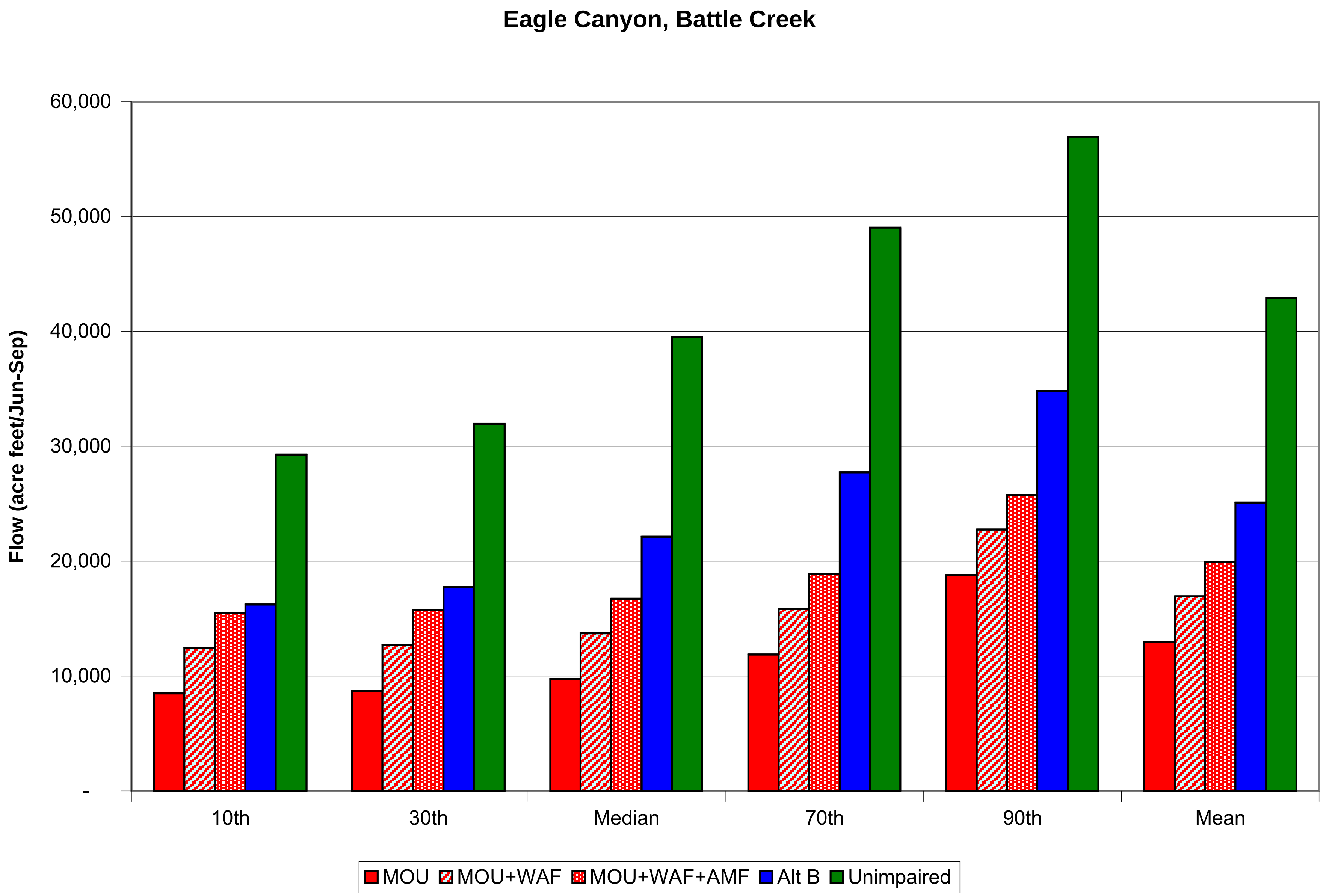
Acre Feet/Jun-Sep Comparison



1962-2002 Jun-Sep flow derived from modified RVI/Navigant model. 10% - 90% and mean summer flows shown. WAF ($3 mil): ~8000 AF. AMF ($3 mil): ~6000 AF. $50/mWh, 2.5% inflation, 9.53% discount rate, purchases in summer only, after 2014.

Figure A-5, Summer Acre Feet

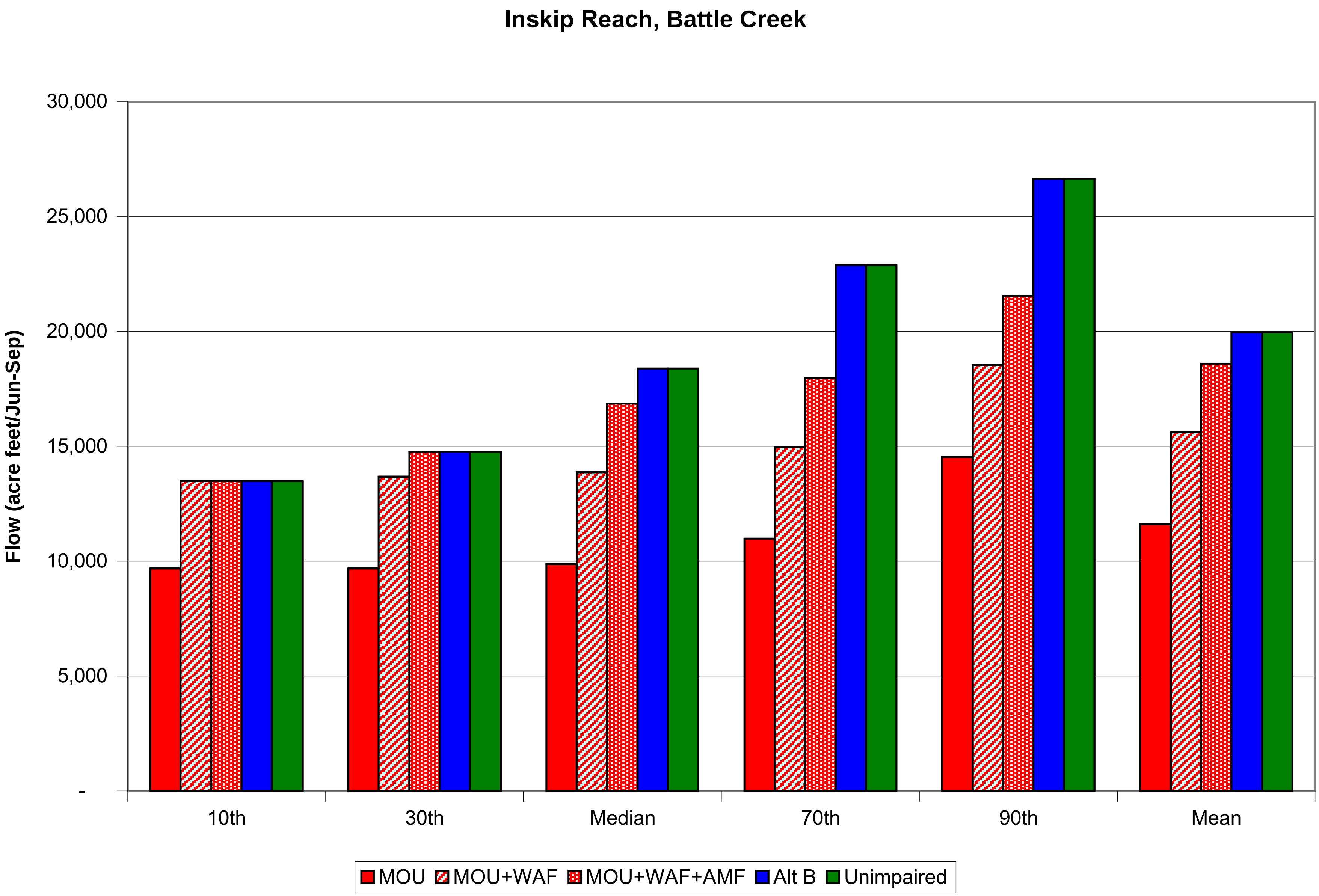
Acre Feet/Jun-Sep Comparison



1962-2002 Jun-Sep flows derived from modified RVI/Navigant model. 10% - 90% and mean summer flows shown. WAF ($1.5 mil): ~4000 AF. AMF ($1.5 mil): ~3000 AF. $50/mWh, 2.5% inflation, 9.53% discount rate, post 2014, summer only, equal NF/SF.

Figure A-6, Summer Acre Feet

Acre Feet/Jun-Sep Comparison



1962-2002 Jun-Sep flows derived from modified RVI/Navigant model. 10% - 90% and mean summer flows shown. WAF ($1.5 mil): ~4000 AF. AMF ($1.5 mil): ~3000 AF. $50/mWh, 2.5% inflation, 9.53% discount rate, post 2014, summer only, equal NF/SF.

Appendix II

Battle Creek Economics Memoranda

Revised April 11, 2004 to reflect April 10 revised project costs.
All references can be downloaded at www.calhrc.org/battlecreek.htm.

March 11, 2004

TO: CHRC

FROM: David Marcus

SUBJECT: Economic reasonableness of 8-dam removal option for Battle Creek hydroelectric projects

I. Introduction

PG&E and others have agreed through an MOU to a 5-dam removal option for the Battle Creek hydroelectric projects, with fish passage facilities to be built at the other three dams. Recent increases in the estimated cost of those fish passage facilities has led to renewed interest in the option of removing all 8 dams, thereby avoiding the cost of constructing and maintaining new fish passage facilities. This memo gives a brief review of the economic reasonableness of such an option.

II. Differences between the two cases

Under the MOU alternative, the average annual generation of the Battle Creek projects is 162.17 gwh per year.[1] With 8-dam removal, the average annual generation is 124.25 gwh per year.[2] Thus the 8 dam case requires an average of 37.92 gwh per year of replacement energy. On the other hand, the MOU case has capital costs which are $17.64 million higher than the 8-dam case, in June 2003 dollars.[3] It also has O&M costs which are $577 thousand higher each year, in 2003 dollars.[4] The NPV of the O&M costs differential, over the period 2005-2026, inclusive, is $6.64 million[5] using an inflation rate of 3% and a discount rate of 9%,[6] or 11.55 times the annual differential in 2003 dollars.[7] There are various other small differences between the two cases which offset one another.[8] Finally, there are future capital addition costs, where the MOU case will cost $120 thousand per year more than the 8 dam case, in 2003 dollars.[9] When grossed up for the income tax effects and return on rate base, this $120 thousand per year cost difference corresponds to a ratepayer difference of $171 thousand per year.[10] Using the same 11.55 factor to convert annual 2003

[1] Battle Creek Economics.xls, "Economic Summary" tab, cell D6.
[2] Battle Creek Economics.xls, "Economic Summary" tab, cell I6.
[3] Battle Creek Economics.xls, "Economic Summary" tab, cell D7 minus cell I7.
[4] Battle Creek Economics.xls, "Economic Summary" tab, cells D27 and D28 minus cells I27 and I28.
[5] Battle Creek Economics.xls, "Economic Summary" tab, cell D54 minus cell I54.
[6] Battle Creek Economics.xls, "Economic Summary" tab, cells A47, A48.
[7] Battle Creek Economics.xls, "Economic Summary" tab, 1000 times cell C120 divided by cell C22.
[8] One-time Screen/Ladder repairs, construction outage costs, FERC license amendment costs. See Battle Creek Economics.xls, "Economic Summary" tab, cells D30 and D35 and D36, minus cells I30 and I35 and I36.
[9] Battle Creek Economics.xls, "Economic Summary" tab, cell D10 minus cell I10.
[10] Battle Creek Economics.xls, "Economic Summary" tab, cell D26 minus cell I26.

costs into 2005-2026 NPV costs, the future capital additions of the MOU case will be $2.0 million higher than the future capital costs of the 8-dam case.

Putting all the cost numbers together, the 8-dam case saves $17.6 + $6.7 + $2.0 = $26.3 million dollars compared to the MOU case, in year 2003 NPV terms. The question is whether this savings is more or less than the cost of replacing the average 37.92 gwh per year of generation which would be lost under the 8-dam case.

III. Cost of replacement generation

The Battle Creek Economics spreadsheet uses an energy value of $51.1 per Mwh, or 5.16 cents per kwh, for 2003,[11] and then escalates that price at 3 percent per year.[12] Using that price, the NPV of 2005-2026 replacement energy purchases would be $51.1/Mwh x 1000 Mwh/gwh x 37.92 gwh/year x 11.55 NPV conversion factor = $22.4 million. This is $3.9 million less than the capital and operating cost penalty associated with the MOU case, and suggests that the 8-dam case is economically preferable by this amount.[13]

However, $51.1 per Mwh may not be the appropriate number to use. The intention of both CHRC and PG&E is that if the 8-dam case is to be adopted, then replacement energy for the decrease in Battle Creek generation should come from renewable resources. Renewable resource generation may have higher costs than the general market prices used in the Battle Creek Economics spreadsheet.

The California Energy Commission, in its October 2003 “Electricity and Natural Gas Assessment Report,” CEC publication P100-03-014, estimates the levelized cost of wind generation, in 2002 dollars.[14] The CEC estimates are thus structured the same way as the prices in the Battle Creek Economics spreadsheet, with an initial year price that escalates each year thereafter at the rate of inflation. The CEC cost estimate for wind generation is 4.93 cents per kwh.[15] Adding 3 percent for inflation from 2002 to 2003, the CEC number corresponds to a 2003 price for wind of $50.8 per Mwh, extremely close to (and slightly lower than) the $51.1/Mwh price in the Battle Creek Economics spreadsheet for energy in 2003. Thus it is reasonable to use the Battle Creek Economics values to compare the MOU to the 8-dam alternative.

Alternatively, one can calculate what price for replacement energy would eliminate the $3.9 million cost advantage held by the 8-dam case over the MOU case when replacement energy is priced at $51.1/Mwh in 2003 dollars. To make the two cases equal, the NPV of replacement energy must be equal to $26.3 million, as shown in the previous section. Based on an 11.55 NPV conversion factor, that corresponds to an annual replacement energy cost of $26.3/11.55 = $2.27 million in 2003 dollars. Since the average quantity of replacement energy is 37.92 gwh per year, or 37,920 Mwh per year, the breakeven price for replacement energy would be $2.27 million/37,920 Mwh = $60.65/Mwh in 2003 dollars. Escalating forward to 2004 dollars, the breakeven price would be $61.78 per Mwh. This is well above the CEC’s price for wind energy.

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[11] Battle Creek Economics.xls, “Economic Summary” tab, cell C22 divided by cell C6.

[12] Battle Creek Economics.xls, “Economic Summary” tab, cell A47.

[13] Battle Creek Economics.xls, “Economic Summary” tab, comparing cells D55 and I55, shows a $2.2 million NPV advantage for the 8-dam case. However, cells D55 and I55 do not refelect the $2.0 million NPV advantage of the 8-dam case over the MOU case with respect to future capital additions, discussed above.

[14] CEC, Electricity and Natural Gas Assessment Report,” CEC publication P100-03-014, p. B-2.

[15] CEC, Electricity and Natural Gas Assessment Report,” CEC publication P100-03-014, p. B-3.

IV. Other issues

A. Discount rate

The Battle Creek Economics spreadsheet uses a discount rate of 9 percent per year. Elsewhere, a discount rate of 9.53 percent per year has been used as more representative of the PG&E rate of return.[16] Using a higher discount rate will increase the cost advantage of the 8-dam case over the MOU case. With a 9.53% discount rate instead of a 9% discount rate, the NPV conversion factor would be 11.00 instead of 11.55. Holding all other assumptions constant, the $3.9 million cost advantage of the 8-dam case over the MOU case would increase to $4.55 million.[17]

B. Inflation rate

The Battle Creek Economics spreadsheet uses an inflation rate of 3 percent per year. Elsewhere, an inflation rate of 2.5 percent per year has been used for both O&M and energy prices when evaluating the Battle Creek projects.[18] Lower inflation rate assumptions increase the cost advantage of the 8-dam case over the MOU case. With a 2.5% inflation rate instead of a 3% inflation rate, the NPV conversion factor would be 11.00 instead of 11.55.With a 2.5 percent inflation rate, the $3.9 million cost advantage of the 8-dam case over the MOU case would increase to $4.55 million.[19]

C. Combined effect of changing inflation rate and discount rate assumptions

If both the discount rate and inflation rate assumptions are changed to match those in the Navigant spreadsheet, the NPV conversion factor would be 10.47 instead of 11.55. The $3.9 million cost advantage of the 8-dam case over the MOU case would increase to $5.2 million.[20]

D. Replacing capacity

The Battle Creek projects provide a small amount of reliable capacity in dry years. Looking at 1977 hydrology, in the months of July and August when PG&E's annual peak normally occurs (these are the months for which PG&E's reserve planning was typically done, historically), the difference between the MOU and 8-dam cases is 1553-1774 Mwh per month.[21] This corresponds to an output difference of 2.1-2.4 Mw. If the 38 gwh difference between the cases were replaced with wind generation from wind farms with an annual capacity factor of 30 percent, it would take 14.4 Mw of wind generation to produce 38 gwh per year.[22] In order for 14.4 Mw of installed wind capacity to produce 2.1-2.4 Mw

[16] Navigant spreadsheet, "Proforma Analysis" tab, cell B9.
[17] $17.6 for capital costs, $6.3 million for O&M, $1.9 million for capital adjustments, offset by $21.3 million for replacement power costs.
[18] Navigant spreadsheet, "Proforma Analysis" tab, rows 7 and 8.
[19] $17.9 for capital costs, $6.3 million for O&M, $1.9 million for capital adjustments, offset by $21.3 million for replacement power costs.
[20] $17.9 for capital costs, $6.1 million for O&M, $1.8 million for capital adjustments, offset by $20.3 million for replacement power costs.
[21] Navigant spreadsheets for MOU and 8-dam cases, "Tier 1" tab," cells M117 and N117.
[22] 14.4 Mw x 8760 hours/year x 30% capacity factor x 1 gwh/1000 Mwh.

of firm capacity, the wind generation would have to have a firm capacity rating equal to 15-17 percent of its installed capacity, a quite small fraction. In the extreme case where wind generation produced no firm capacity at all (the wind never blew on summer afternoons), the economic cost to replace 2.1-2.4 Mw of firm hydro capacity would be small. At current prices of under $100/kw-year for year-round capacity, 2.4 Mw would cost under $240 thousand per year. Using an 11.55 NPV conversion factor, as discussed above, the NPV cost of replacement capacity would be under $2.8 million, not enough to offset the $3.9 million cost advantage of the 8-dam case. If PG&E only bought summer replacement capacity, the costs would be significantly less.

From: David Marcus [dmarcus2@mindspring.com]
Sent: Friday, March 12, 2004 11:43 AM **(UPDATED April 22 to reflect new costs)**
To: Stephen Wald
Subject: Re: foregone power memo

Steve,

After our conversation with PG&E, I have revisited my Battle Creek analysis in light of issues raised by PG&E. I checked PG&E's current rate of return on capital and found it to be 9.24%. I believe this is the correct number to use in comparing cost streams over different time periods, whether from a ratepayer or stockholder point of view. I incorporated this number into the "Battle Creek Economic Summary" spreadsheet (cell A49). I then modified the spreadsheet in several ways:

1. I added a line to show, and allow the user to vary, the assumed 2004 energy price (cell A48).

2. I modified the summary line entitled "Screen, Ladder Decommissioning Costs" (row 53 in the modified spreadsheet; previously row 52) to put it in 2004 dollars, consistent with the title of the section on row 51 (row 53 was previously in 2003 dollars, a point I had not noticed before today). This makes the 8-dam alternative more attractive by $0.5 million.

3. I modified the summary line entitled "Increased O&M" (row 55 in the modified spreadsheet; row 54 in the original spreadsheet) so that future capital additions (row 26) are accounted for in the summary.

4. I extended the replacement power calculations to include the years 2027-2035 (new rows 121-129), per PG&E's concern that it get post-relicensing replacement power.

5. I changed the expected implementation period to be 2006-2035 instead of 2005-2026 (see rows 130-131), per PG&E's suggestion. This change affects both "Replacement Power Costs" (new row 54) and "Increased O&M" (new row 55). The deferred start of the implementation reduces the NPV of both the replacement power costs and the O&M costs, while the longer time period increases them. The net effect is a small increase, $2 million, in the NPV of the difference between the MOU and Alt. B (cell D129 minus cell I129, versus cell D130 minus cell I130), a difference which is itself about 1/3 offset by the effect of the different implementation period on O&M cost savings (the difference is the percentage difference between cells C129 and C130, times the dollar difference between cells D55 and I55). So the net impact of changing the implementation period is only about $1.3 million in NPV terms.

6. I added note 4 (rows 89-91) which points out that if the implementation delay to 2006 affects Alt. B but not the MOU case, then the MOU case will have $3.2 million in NPV costs in 2005 for replacement power costs and O&M costs that are not accounted for elsewhere in the modeling.

7. I then set the 2004 energy price to the level which would make the "Expected Case" costs of the MOU and Alt. B be the same. This price turns out to be $57.5 per Mwh. As my previous memo indicated, the CEC believes that wind energy can be procured for well under $57 per Mwh.

I have attached the modified spreadsheet. You will find that if you change the inflation rate to 2.5% from 3% (cell A47), the breakeven energy price for replacement energy changes to $59.5/Mwh. If you change the discount rate to 7.85% the breakeven 2004 energy price changes to $52/Mwh. If you change both the inflation rate and the discount rate, the breakeven 2004 energy price changes to $53.7/Mwh. All of these prices are in the range of prices that I believe is attainable for long-term wind contracts. Please call if you have any questions.

April 23, 2004

TO: File
FROM: Stephen Wald, CHRC
SUBJECT: Battle Creek Incremental Forgone Power Under Alt B

On April 22, 2004, PG&E informed CHRC that they wanted to change their estimate of the increment of power lost going from the MOU to Alt B, from 38 annual gigawatt hours to 50 gwh, based on the Navigant power model. PG&E said the Navigant model was more accurate and more sophisticated than their prior internal calculations.

However, the original Navigant model to which PG&E referred uses average monthly hydrology that does not match current USGS data from its website[1]. Corrected, the Navigant model shows the increment of power lost under Alt B to be 33 gwh in 1989, the selected average year.[2]

Using the Battle Creek Economic Summary spreadsheet, modified as described in David Marcus's March 12 email memo to CHRC, and the following assumptions: 33 gwh power differential, 3% inflation, and 9.24% discount rate (PG&E's weighted average cost of capital), PG&E could be compensated for 30 years of forgone power under Alt B at $64.7/mwh at the same total cost to the Bay Delta Authority.[3]

PG&E has also asked the question, even if we were compensated for 30 years, what happens in year 31? The breakeven price for 50 years of forgone power, using the same assumptions above, is $59.5/mwh.

Including $3 million in private foundation funding for Alt B, the 30 and 50 year breakeven power prices would be $71.6 and $65.5 per mwh, respectively.

These values are well above the projected price of power, and within the range of public estimates of renewable power, as well: $46.25 wind (CEC 2003), $45.31 geothermal (CEC 2003), $29-67 biomass (Oregon DOE 2004).

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[1] Compare the Coleman Fish Hatchery Flows tab on the original Navigant model (http://www.calhrc.org/2003-09-22 Current Restoration Project.xls - 2.5 MB) with http://nwis.waterdata.usgs.gov/nwis/monthly/?site_no=11376550&agency_cd=USGS.

[2] Corrected Navigant model, http://www.calhrc.org/2004-03-09 Current Restoration Project.xls. MOU case on tab "Tier 1", Alt B case on tab "Tier 2".

[3] http://www.calhrc.org/Battle Creek Economic Summary - 30 years. This table is shown on the following two pages, with the input assumption of $50/mwh power prices for 2004. Alt B yields $28.1 million in NPV savings over the MOU that can be applied to the increment of forgone power.

BATTLE CREEK SALMON RESTORATION ECONOMIC SUMMARY USING FERC'S CURRENT COST METHOD

		30-Oct-03					added alts Oct03	added alts Oct03	added alts Nov03
		Alt 1	**Alt 2**	**Alt 3**	**Alt 4**	**Alt 5**	**Alt 6**	**Alt 7**	**Alt 8**
		Resume existing FERC License conditions	MOU, with cost sharing	Install screens and ladders at diversions, …	MOU plus decommission Eagle Canyon	MOU plus decommission Eagle Canyon; w/o South Lower Ripley and Soap decommissioning	Decommission Entire Battle Creek Hydro Project	Decommission all diversion downstream of Natural Barriers	Decommission all facilities downstream of Natural Barriers
		No Action Alternative	**Five Dam Removal Alternative**	**No Dam Removal Alternative**	**Six Dam Removal Alternative**	**Three Dam Removal Alternative**	**Complete Removal Alternative**	**Remove downstream diversions**	**Remove downstream diversions**
ln 1	**Average Annual Energy, GWh**	**257.63**	**183.4**	**190.56**	**137.05**	**159.57**	**0**	**149.73**	**59.3**
ln 2	**Total construction costs + ln15 (USBR June '03), $millions**		**$65,334**	**$62,443**	**$61,076**	**$63,980**	**$93,990**	**$47,697**	**$54,525**
	One-Time and Annually Recurring Cost Descriptions ($1,000's)								
ln 3	Unrecovered Sunk Costs, or Net Book Value	**$34,600**	**$34,600**	**$34,600**	**$34,600**	**$34,600**	**$34,600**	**$34,600**	**$34,600**
ln 4	Future Capital Additions (per year)	**$300**	**$300**	**$300**	**$300**	**$300**	**$0**	**$180**	**$150**
ln 5	Operation and Maintenance (per year)	**$1,700**	**$1,783**	**$1,880**	**$1,750**	**$1,947**	**$0**	**$1,360**	**$1,020**
ln 6	Storm repairs (every 10 years)	**$500**	**$950**	**$1,400**	**$800**	**$800**	**$0**	**$400**	**$300**
ln 7	Construct Screens & Ladders, w/ connectors/byp	**$0**	**$29,033**	**$47,424**	**$23,160**	**$30,135**	**$0**	**$0**	**$0**
ln 8	One-time Screen/Ladder repairs	**$0**	**$600**	**$1,200**	**$400**	**$600**	**$0**	**$0**	**$0**
ln 9	Decommissioning costs, w/ connectors/bypass	**$0**	**$19,145**	**$0**	**$22,897**	**$18,826**	**$70,800**	**$36,007**	**$33,335**
ln 10	Envir Compliance, Montr & Mitgtn	**$0**	**$9,690**	**$9,690**	**$9,690**	**$9,690**	**$23,190**	**$11,690**	**$21,190**
ln 11	MLFT Pathogen Problem Resolution	**$0**	**$2,329**	**$2,329**	**$2,329**	**$2,329**	**$0**	**$0**	**$0**
ln 12	Future Water Acquisition	**$0**	**$3,000**	**$3,000**	**$3,000**	**$3,000**	**$0**	**$0**	**$0**
ln 13	Construction outage costs	**$0**	**$1,259**	**$955**	**$841**	**$790**	**$0**	**$841**	**$0**
ln 14	FERC License Amendment/EIS/EIR	**$0**	**$4,750**	**$4,750**	**$4,750**	**$4,750**	**$9,500**	**$5,700**	**$5,700**
ln 15	Reimbursed Foregone Power (net present value)	**$0**	**$2,137**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
ln 16	2003 Power Benefits (per year)	**$12,506**	**$8,903**	**$9,250**	**$6,653**	**$7,746**	**$0**	**$7,268**	**$2,879**
	FERC Current Cost Method (Annual cost in 2003 dollars, $1,000's/yr)								
ln 17	Unrecovered Sunk Costs, or Net Book Value	**$4,844**	**$4,844**	**$4,844**	**$4,844**	**$4,844**	**$4,844**	**$4,844**	**$4,844**
ln 18	Future Capital Additions	**$427**	**$427**	**$427**	**$427**	**$427**	**$0**	**$256**	**$213**
ln 19	Operation and Maintenance	**$1,700**	**$1,783**	**$1,880**	**$1,750**	**$1,947**	**$0**	**$1,360**	**$1,020**
ln 20	Storm repairs	**$140**	**$266**	**$392**	**$224**	**$224**	**$0**	**$112**	**$84**
ln 21	Construct Screens & Ladders	**$0**	**$4,065**	**$6,639**	**$3,242**	**$4,219**	**$0**	**$0**	**$0**
ln 22	One-time Screen/Ladder repairs	**$0**	**$84**	**$168**	**$56**	**$84**	**$0**	**$0**	**$0**
ln 23	Decommissioning costs	**$0**	**$2,680**	**$0**	**$3,206**	**$2,636**	**$9,912**	**$5,041**	**$4,667**
ln 24	Envir Compliance, Montr & Mitgtn	**$0**	**$1,357**	**$1,357**	**$1,357**	**$1,357**	**$3,247**	**$1,637**	**$2,967**
ln 25	MLFT Pathogen Problem Resolution	**$0**	**$326**	**$326**	**$326**	**$326**	**$0**	**$0**	**$0**
ln 26	Future Water Acquisition	**$0**	**$420**	**$420**	**$420**	**$420**	**$0**	**$0**	**$0**
ln 27	Construction outage costs	**$0**	**$122**	**$93**	**$82**	**$77**	**$0**	**$82**	**$0**
ln 28	FERC License Amendment	**$0**	**$665**	**$665**	**$665**	**$665**	**$1,330**	**$798**	**$798**
ln 29	Reimbursed Foregone Power	**$0**	**$207**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
ln 30	2003 Power Benefits	**$12,506**	**$8,903**	**$9,250**	**$6,653**	**$7,746**	**$0**	**$7,268**	**$2,879**
ln 31	**Total Cost of Project Power**	**$7,111**	**$16,831**	**$17,211**	**$16,598**	**$17,225**	**$19,333**	**$14,129**	**$14,593**
ln 32	**Going-forward Cost of Project Power**	**$2,267**	**$11,987**	**$12,367**	**$11,754**	**$12,381**	**$14,489**	**$9,285**	**$9,749**
ln 33	**Total Net benefits (including NBV)**	**$5,395**	**-$7,928**	**-$7,960**	**-$9,946**	**-$9,479**	**-$19,333**	**-$6,861**	**-$11,714**
ln 34	**Net benefits on a going-forward basis (excluding NBV)**	**$10,239**	**-$3,084**	**-$3,116**	**-$5,102**	**-$4,635**	**-$14,489**	**-$2,017**	**-$6,870**

3.0% Escalation rate $50.0 2004 energy price, $/Mwh 9.24% Discount Rate							
	Alt 2	**Alt 3**	**Alt 4**	**Alt 5**	**Alt 6**	**Alt 7**	**Alt 8**
SENSITIVITY ANALYSES	MOU, with cost sharing	Install screens and ladders at diversions, …	MOU plus decommission Eagle Canyon	MOU plus decommission Eagle Canyon; w/o South Lower Ripley and Soap decommissioning	Decommission Entire Battle Creek Hydro Project	Decommission all diversion downstream of Natural Barriers	Decommission all facilities downstream of Natural Barriers
	Net Present Value cost in 2004 dollars, $millions						
I. EXPECTED CASE							
Screen, Ladder, Decommissioning Costs	**$67.3**	**$64.3**	**$62.9**	**$65.9**	**$96.8**	**$49.1**	**$56.2**
Replacement Power Costs	**$47.9**	**$43.3**	**$77.8**	**$63.2**	**$166.1**	**$69.6**	**$128**
Increased O&M	**$2.8**	**$5.7**	**$1.8**	**$4.4**	**($30.1)**	**($7.2)**	**($12.6)**
Total	**$117.9**	**$113.3**	**$142.5**	**$133.5**	**$232.8**	**$111.6**	**$171.5**
II. POWER VALUE UNCERTAINTY							
A. 4 cent power values (in 2004 $)							
Screen, Ladder, Decommissioning Costs	**$67.3**	**$64.3**	**$62.9**	**$65.9**	**$96.8**	**$49.1**	**$56.2**
Replacement Power Costs	**$38.3**	**$34.6**	**$62.2**	**$50.6**	**$132.9**	**$55.7**	**$102.3**
Increased O&M	**$2.8**	**$5.7**	**$1.8**	**$4.4**	**($30.1)**	**($7.2)**	**($12.6)**
Total	**$108.4**	**$104.7**	**$126.9**	**$120.9**	**$199.6**	**$97.6**	**$145.9**
B. 6 cent power values (in 2004 $)							
Screen, Ladder, Decommissioning Costs	**$67.3**	**$64.3**	**$62.9**	**$65.9**	**$96.8**	**$49.1**	**$56.2**
Replacement Power Costs	**$57.4**	**$51.9**	**$93.3**	**$75.9**	**$199.4**	**$83.5**	**$153.5**
Increased O&M	**$2.8**	**$5.7**	**$1.8**	**$4.4**	**($30.1)**	**($7.2)**	**($12.6)**
Total	**$127.5**	**$122.0**	**$158.0**	**$146.2**	**$266.1**	**$125.5**	**$197.0**
III. CONSTRUCTION COST UNCERTAINTY							
A. Construction costs 10% less than expected							
Screen, Ladder, Decommissioning Costs	**$60.6**	**$57.9**	**$56.6**	**$59.3**	**$87.1**	**$44.2**	**$50.5**
Replacement Power Costs	**$47.9**	**$43.3**	**$77.8**	**$63.2**	**$166.1**	**$69.6**	**$127.9**
Increased O&M	**$2.8**	**$5.7**	**$1.8**	**$4.4**	**($30.1)**	**($7.2)**	**($12.6)**
Total	**$111.2**	**$106.9**	**$136.2**	**$127.0**	**$223.2**	**$106.6**	**$165.8**
B. Construction costs 25% more than expected							
Screen, Ladder, Decommissioning Costs	**$84.1**	**$80.4**	**$78.6**	**$82.4**	**$121.0**	**$61.4**	**$70.2**
Replacement Power Costs	**$47.9**	**$43.3**	**$77.8**	**$63.2**	**$166.1**	**$69.6**	**$127.9**
Increased O&M	**$2.8**	**$5.7**	**$1.8**	**$4.4**	**($30.1)**	**($7.2)**	**($12.6)**
Total	**$134.8**	**$129.4**	**$158.2**	**$150.0**	**$257.0**	**$123.8**	**$185.5**

NOTES:

1 Forced outages and routine maintanance outages would increase with the number of added screen and ladders. The replacement power costs associated with these changes are expected to be minor, but are not included in the analysis.

2 The reduced energy production due to the Salmon Restoration would most likely need to be replaced by a renewable resource. The replacement power cost for renewable electricity could be about 6.5 cents/kWh.
A scenario analysis to reflect this increased renewable replacement power cost is not included.

3 The measures to eliminate mixing of the north fork and south fork waters would reduce the operational flexibility of the hydrosystem. This loss of flexibility has not been included in the economic analysis.

4

or 68.72 gwh. At a market price in 2005 of $50/Mwh, 68.72 gwh would cost $3.44 million, which would equal $3.1 million in 2004 NPV terms. Implementing the MOU 1 year sooner than other options would also increase its costs by $0.1 million because of increased O&M costs in 2005 (difference between cells C11 and D11).

Appendix III

Methods

Hydrology

RMI/Navigant prepared a flow and economic model[1] for Battle Creek designed to use average monthly flow data from USGS gage 11376550. CHRC updated the model to reflect current monthly flow data from the USGS website[2]. CHRC further modified the model[3] to use average daily data from the same gage[4]. Navigant model flow partitions, spring inputs, and project facility flow capacities are as follows:

Based on Area Method			
	Drainage Area		
Measurement Point	Sq. Mi.	Percent	Source
Coleman Fish Hatchery	357.0	100.00%	USGS
Al Smith Diversion	65.0	18.21%	Estimate of N. Fork at Confluence with Deer Creek (Payne, Table 4).
Keswick Diversion	80.0	22.41%	Estimate of N. Fork above Bailey Creek (Payne, Table 4)
NBCF Diversion	133.0	37.25%	USGS
Eagle Canyon Diversion	186.0	52.10%	USGS
Wildcat Diversion	189.0	52.94%	USGS
South Diversion	66.7	18.68%	USGS
Inskip Diversion	88.3	24.73%	USGS
Coleman Diversion	102.0	28.57%	USGS
Baldwin Creek	14.0	3.92%	Estimate of Baldwin Creek at Mouth (Payne, Table 4)

Battle Creek Watershed Spring Flows		
Spring	Flow (cfs)	Inflow Point
High North Fork Springs	20.0	Above Al Smith Diversion
Upper Eagle Canyon Springs	15.0	Above Eagle Canyon Diversion
Lower Eagle Canyon Springs	0.0	Above Wildcat Diversion
Baldwin Creek Springs	15.0	Above Pacific Power Diversion
Upper Ripley Creek Springs	2.0	Into South Diversion
Lower Ripley Creek Springs	3.0	Into South Diversion
Soap Creek Springs	10.0	Into South Diversion

Flow Capacities (in cfs) of Battle Creek Project Facilities	
Powerhouses	
Volta I	128
Volta II	128
South	222
Inskip	283
Coleman	380
Diversions	
Al Smith Canal	64
Keswick Canal	64
N. Battle Feeder Canal	50
Cross-Country Canal	150
Eagle Canyon Canal	64
Wildcat Canal	18
Pacific Power Canal	15
Asbury Pipe	35
Minimum Requirement in South	0
South Canal	100
Union Canal	222
Inskip Canal	220
Upper Coleman Canal	340
Lower Coleman Canal	380

Figures S-1 to S-6. From Navigant daily data for water years 1962-2002 (1997 excepted), 10%, 30%, 50% (median), 70%, and 90% percentile flows over the 40 year record for each day.

Figures E-1 to E-6. Flow exceedence curves were produced with ranked daily flows for each reach for the noted timeframe (overall and Jun-Sep) over the period of record.

[1] http://www.calhrc.org/2003-09-22 Current Restoration Project.xls – 2.5 MB
[2] http://nwis.waterdata.usgs.gov/nwis/monthly/?site_no=11376550&agency_cd=USGS
[3] http://www.calhrc.org/Battle%20Creek%20daily.xls – 8 MB
[4] http://nwis.waterdata.usgs.gov/nwis/discharge/?site_no=11376550&agency_cd=USGS.

Temperature
Figures T-1 to T-8. Comparative SNTEMP data for Unimpaired, Alt B, and MOU was compiled from existing SNTEMP alternatives 6, 6/4 hybrid as described in the text, and 3, respectively[5]. Dashed lines are shown at Armour (1991) thresholds for egg incubation (58°F), adult holding (62°F), and juvenile rearing (66°F).

Figures C-1 to C-3. SNTEMP flow input comparison contrasts median Navigant monthly flows (derived from daily data set) with SNTEMP normal and dry flows provided by PG&E (Scott Tu). Expected range of flows indicated by braces at the median 90% and 10% percentile daily flows for Jun-Sep.

Conservative flow-based temperature correction estimate of 1°F for Alt B mainstem, June is based upon Figure C-1, which shows SNTEMP Alt B normal flow is at the 10% Navigant flow level. Navigant median Alt B June flow is closer to SNTEMP unimpaired June, which is 4-5°F cooler in Figure T-1. However, the additional Navigant Alt B flow volume is composed of both NF and SF water, whereas the flow in excess of SNTEMP Alt B in unimpaired SNTEMP is entirely NF water (from Volta), and presumably colder.

Conservative validation temperature correction estimate of 1°F for mainstem June and September (all alternatives) is based on SNTEMP Figure 7, which shows model predictions in 1999 consistently exceeded measured temperatures in the mainstem. SNTEMP Table 1[6] states that the 1999 validation study showed a mean error of 2.52°F and a probable error of ±2.16°F for the mainstem. Notes to SNTEMP Table 1 cite a lack of cloud cover data for 1999, but this did not affect the accuracy of model predictions for other stream reaches. An additional note cites a lack of accretion flow data for the mainstem, but this note's meaning and effect could not be determined.

Tables 1 and 2. River mile/temperature estimates. Unimpaired, Alt B, and MOU temperature profiles for each reach in Figures T-1 and T-4 were converted into linear equations (y=mx+b) using MS Excel LINEST function. R-squared values averaged 0.97 for June, 0.98 for September. River miles below temperature thresholds were recorded in 0.1°F increments for each alternative, with and without conservative corrections noted above[7].

Adaptive Management
Navigant estimate of acre feet purchasing power was adopted, rounded to nearest thousand. Acre feet for MOU, Alt B, and Unimpaired were calculated from converted daily cfs data for the applicable period (annual, Jun-Sep).

[5] http://www.calhrc.org/026_11-00_256.doc, http://www.calhrc.org/ProfileAlt3.xls, http://www.calhrc.org/ProfileAlt4.xls, http://www.calhrc.org/ProfileAlt6.xls.
[6] http://www.calhrc.org/026_11-00_256.xls
[7] http://www.calhrc.org/SNTEMP mileage model.xls – 2 MB.